Electrochemical and Metallurgical Industry

VOL. III. NEW YORK, MAY, 1905. No. 5.

Electrochemical and Metallurgical Industry

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,
[*Incorporated.*]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D. .....*President.*
E. F. ROEBER, PH. D. .....*Editor.*

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

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Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

This Journal is non-returnable by newsdealers. Readers who are not subscribers should place a standing order with the newsdealer, in order to obtain it regularly.

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Boston Meeting of the American Electrochemical Society.

That the Boston meeting of the American Electrochemical Society—a full report of which is given in this issue—would be a most enjoyable and profitable affair, long to be remembered by all attending it, was a priori certain to everybody who knows the spirit of the city of the Massachusetts Institute and Harvard University, and who knows the pluck and energy of the local Boston members, with Dr. Walker and Dr. Talbot as chairman and secretary. The meeting could not turn out anything but a success. The only question was how many out-of-town members would attend. Their number was about forty, and may seem small in comparison with the total membership, but we have attended general meetings of far older and larger national engineering societies which were afterwards voted a great success, and yet had a smaller attendance than the Boston meeting. Nevertheless, the question is decidedly open for discussion, what can be done to attract a larger proportion of the general membership to future meetings.

It is an old saying that two general meetings a year are one too many, and this argument seems to be substantiated by the fact that most national engineering societies hold only one general meeting a year. However, in the case of the American Electrochemical Society this argument is refuted by the quantity and quality of papers which its members have been able to present twice a year at each meeting since the formation of the Society. On the other hand, the fact remains that the American Electrochemical Society has enlisted in its membership a great many members of the American Institute of Electrical Engineers, the American Chemical Society and the American Institute of Mining Engineers, and these three Societies are to hold general meetings at different places either in May or June, thus closely following the Boston meeting. The present strength of electrochemistry rests on the fact that it deals with a borderland of sciences and arts, full of virgin soil, and as President Eliot, of Harvard University, remarked in his delightful little speech at the reception in Harvard Union, it is on such borderland that most important developments generally take place. It is very similar with the development of nations.

The reason for this is evident; the separation of sciences and arts is not natural, but inherent in the historical development of mankind; each science and each art represents the results obtained by pushing a single point of view as far as it will go. Thus any science and any art, when getting fully developed, tends to become one-sided. The only possible remedy is then evident. Electrochemists, while apparently specializing, are really uniting chemical, metallurgical and electrical sciences and engineering. It would thus appear to

be decidedly a step forwards in the work of the American Electrochemical Society if it would try to coöperate more closely with its national sister societies. We have no idea of a "merger" or of giving up in the least the identity of the Electrochemical Society. But an attempt to hold, at least, once a year a joint meeting with one of the sister societies, should bring good results; one year it might be with the chemists, another year with the mining engineers, and another year with the electrical engineers. Such joint meetings would strongly tend to strengthen the cause in which the Society is enlisted. Moreover, a larger proportion of the membership would naturally be attracted to such meetings.

The programme of papers at the Boston meeting was excellent, although the distribution of the papers over the three sessions was somewhat unbalanced, the last session being too heavily loaded with splendid material. In one point the programme had a novel feature, which cannot be too strongly recommended. This is the presentation of various lectures illustrated by experiments and demonstrations, and covering a somewhat large subject. An instance is Dr. Whitney's most interesting lecture on colloids. While perhaps only a small part of this lecture contained hitherto unpublished information, yet it is certain that to most of those present the whole subject was a novel one, and that to all who listened to this lecture the lucid exposition of the subject offered plentiful food for thought. To read the printed paper is no substitute for listening to such a lecture. Thus the argument which one often hears that it is easier and more convenient to read the papers either in abstract after the close of the meeting in the engineering journals, or in full after publication in the Society's Transactions, breaks completely down with respect to such lectures with experimental demonstrations. By seeing for himself how a process takes place, one gets a far clearer and more intimate acquaintance with its nature than by simply reading a description of the process. Lectures of this kind have been in the past a regular feature of the annual conventions of the German Bunsen Society, and have contributed much towards their success. If the members of the American Electrochemical Society learn that they will have an opportunity to listen to several lectures of this kind at every general meeting in future, this will act more than anything else to attract a large attendance. For a joint meeting with another society it would not be difficult to select subjects which should be of interest to everybody.

By-Products.

We have made repeated references in these columns to the changes in American metallurgy in the past century. It has always been our endeavor to view these changes in their broadest aspects, and to point out how the interaction of industrial forces results in equilibrium from change. Fundamentally the doctrine of evolution defines the course of these movements. Growth from the simple to the complex is the normal growth for any organism. It is thus but natural to find in all industries a tendency to increase the number of products, and especially by-products made from what would otherwise be waste material in the main process. Such a change is the normal one, from simplicity to complexity of products. The creature that can use several things for food has a better chance for life than the creature dependent on only one kind of food. Examples of this phase of industrial evolution are seen everywhere in America. The boast of the great Western beef-packing establishments that they sell everything but the intangible squeal, is a trite commonplace of the daily press. Their profits are in their by-products. The Standard Oil Company transports and refines the crude oil cheaply, and sells besides its illuminating oil a variety of products ranging from naphtha to petroleum coke. The millions it disburses in dividends and investments from income are sustained by its large output and varied sources of profit.

About the prettiest example of by-product working can be seen at the works of the Pennsylvania Salt Company at Natrona. Here Rio Tinto pyrites is roasted to produce a sulfurous gas used for the manufacture of sulfuric acid. The cinder from this operation is mixed with common salt, and given a chloridizing roast to render the copper soluble. This copper is then leached out, and the leached "blue-billy" (nearly a pure oxide of iron) is sold to the neighboring iron or steel plants and used as an iron ore. The whole scheme is worthy of emulation at other places. A good deal of good iron in the form of iron silicate is going over the dumps at Rossland, Sudbury and Ducktown. Under favorable conditions this iron might have been brought to the center of consumption and used as an iron, copper and sulphur ore. The General Chemical Company, at Pulaski, Va., is developing this same treatment for copper-bearing pyrrhotite ores of Virginia. The reduction of bituminous coal to coke with the production of gas, tar and sulfate of ammonia is increasing in this country, although it never has had the vogue here it has in Germany. Despite its greater capital cost the by-product coke plant will displace in time the old bee-hive oven, as capital becomes more plentiful. The up-to-date brass mill can only meet competition by having special machinery to work up into specialties, like eyelets, etc., waste sheets which otherwise would have only a scrap value. In Germany one of the great causes for the popularity of the basic Thomas converter is the fact that there is a ready market as a fertilizer for its phosphorus-carrying slag. The electrolytic refining of copper has saved enormous sums to the world and reduced the cost of making copper two or four cents a pound. Many other examples could be cited, but these suffice to show the importance of the subject. The ramification of industry and the utilization of waste are logical events in our industrial developments.

Of course, the by-product business can easily be overdone and carried to extremes. If a large structure fails for improper design its failure causes more destruction than a smaller structure would. So an immense industrial organization planned to create by a *fiat* many co-ordinated factories, springing full-grown in the wilderness, fails from unwieldiness, and great is the fall thereof. A well-known ill-starred Western metallurgical and power company was all right in theory, but it never made much money as first organized. Sir Joshua Reynolds, the great English painter of the eighteenth century, when asked about the secret of his mixing paints replied, "With brains, sir!" By-products should also be mixed "with

brains, sir." Some prosaic people think that investments should pay interest in coin of the realm and not in "hot air." Perhaps the greatest application of the by-product proposition can be made by the trusts. Within a great corporation proper co-operation allows of many "intercompany" economies. Stability of the trust is such that improvements and developments which could not be justified in a concern that "could not see itself ahead in ore contracts over two years," can be legitimately undertaken. In this case, paradoxical as it may seem, stability is the cause of progress. The advantages of diversified production are obvious. There is an increase in receipts without a corresponding increase in administration expenses. This alone makes for increased net profits. The concern is rendered independent of the market for any one commodity. It obtains its raw material for the by-product free on the spot, and (as in the case with the European zinc smelters) is often relieved of the expense that would be otherwise incurred in disposing of a troublesome waste material. The outside profit is always welcome, and doubly so when it helps tide over hard times and meet competition. "He who maketh two blades of grass grow where grew one before deserveth well of mankind." By-products do exactly this, and honor is due him who intelligently devises means to develop new ones. He is not alone helping himself, but, by the creation of wealth, he is helping the world, and, according to Mr. Andrew Carnegie, this is what makes the true aristocrat.

The Definition of Electrode.

The term electrode is due to Faraday. It was first used in article 662 of the seventh series of his "Experimental Researches." Faraday's words are as follows: "The poles, as they are usually called, are only the doors or ways by which the electric current passes into and out of the decomposing body; and they, of course, when in contact with that body, are the limits of its extent in the direction of the current. The term has been generally applied to the metal surfaces in contact with the decomposing substances; but whether philosophers generally would apply it to the surface of air and water, against which I have effected electrochemical decomposition, is subject to doubt. In place of the term pole I purpose using that of electrode (electron and hodos, a way), and I mean thereby that substance, or rather surface, whether of air, water, metal, or any other body, which bounds the extent of the decomposing matter in the direction of the electric current." The electrode is, therefore, defined as the boundary surface between a conductor of the first class (metallic conductor) and a conductor of the second class (electrolytic conductor). The characteristic property of an electrode is that when a current passes, a chemical change takes place at the electrode, this change being either reduction or oxidation. The latter qualification is necessary, since a chemical change also takes place at the boundary surface of two electrolytes, but in this case it is neither reduction nor oxidation. The fact that somewhere in an electric circuit reduction or oxidation occurs is, however, not sufficient evidence that there is an electrode at that place. In an electric furnace for making ferro-alloys the charge generally consists of oxide of iron, oxide of the metal to be alloyed with iron, and carbon. The chemical action which takes place throughout the furnace is reduction of the metallic oxides and oxidation of the carbon. But in this case the oxidation and reduction take place simultaneously at every place. On the other hand, in a circuit containing an electrolyte with two electrodes, the oxidation takes place at the anode and only there, the reduction at the cathode and only there, there being neither oxidation nor reduction at any other place within the electrolyte. Electrolytic action is thus always characterized by the fact that there is at the one end of the electrolyte reduction, at the other end oxidation.

Faraday's coining of the name electrode from electron and hodos, the way, becomes especially interesting if we consider, in view of the modern electronic theory, what happens at an electrode. Let us consider, for instance, the discharge of chlorine gas at the anode from a chloride solution. The change is from a chlorine ion—*i. e.*, a chlorine atom combined with a negative electron—into a chlorine atom. What happens within the electric circuit is, therefore, that a negative electron gets free from the chlorine ion and passes as a free electron into the metallic conductor. In metallic conductors the electrons are free, in electrolytic conductors they are combined with atoms or radicles in the form of ions. An electrode is, therefore, the door through which the electrons pass out of the combined state into the free state, or the reverse. We may also state the same idea by means of a familiar analogy, originally due, we believe, to Mr. William Stanley. In metals the electricity is transported along a row of men with shovels, each man shoveling the electrons to his next neighbor; in electrolytes the electrons are placed in constant quantities into wheelbarrows, and are carried in the same from one end to the other. The electrode is then the place where the electrons are loaded into the wheelbarrows, or where they are taken out of them.

Whenever there is electrolytic action, the term electrode is properly used for the terminals through which the current is introduced into the electrolyte, whether the latter is a solution or a fused bath. In recent years, however, with the growth of the electric furnace industries it has become customary to speak of electrodes where there is no electrolytic action; thus the carbon or graphite terminals in calcium carbide furnaces, in the Héroult steel furnace, in ferro-alloy furnaces, are often called electrodes. This is an improper use of the term—just as improper as if in the case of an ordinary incandescent lamp the leading-in wires of platinum with which the carbon filament is connected would be called electrodes. (On the other hand, with the Nernst lamp they are electrodes, since the filament is a solid electrolyte.) In some cases, however, we may have electrolysis in electric furnace work, where it is not wanted. An example is the observation of Mr. W. S. Horry, of the Union Carbide Company, that a higher frequency of the alternating current has a distinct beneficial effect on the production of calcium carbide, the explanation being that the furnace charge undergoes electrolytic decomposition if the frequency is too low, which means a diminished efficiency. In this case the graphite rods are simply terminals for the introduction of the current—as far as the desired effect, the production of calcium carbide, is concerned—but they are electrodes with respect to the undesirable decomposition.

Notes.

American Electrochemical Society.—At the meeting of the Board of Directors, held on April 1 in Philadelphia, the following gentlemen were elected members: Daniel McMaster, Rumford Falls, Me.; Arthur D. Little, Boston, Mass.; Marten Hedlund, Haustahammar, Sweden. The names of the following gentlemen will come up for election at the May meeting of the Board of Directors: W. H. Kimball, Portland, Me.; A. S. Ramage, Detroit, Mich.; J. M. Woodward, Washington, D. C.; C. A. Hansen, Madison, Wis.; John Woods Beckman, Tarentum, Pa.

Lehigh University.—A committee has been formed to raise a fund of $80,000, for the purpose of erecting and equipping a Drown Memorial Hall on the campus of the university, to the memory of the late president, Thomas Messinger Drown, who, during the last years of his life, had wished to add to the equipment of the university a building that should be devoted to the social life of the students.—The senior students of metallurgical engineering are assisting Prof. J. W. Richards in the metallurgical laboratory in a series of important determinations concerning the specific heats, up to high temperatures, of the important metallurgical materials and important ores, such as fire-clay, silica, limestone, alumina, iron ores, zinc oxide, etc. A collateral investigation is being made of the latent heats of fusion and specific heats in the molten condition of some important metals which have not before been studied.—The course in electrometallurgy has now laboratory facilities, by the equipment of an electrical laboratory at a cost of about $1,000, rendered possible by the generosity of Mrs. Eckley B. Coxe, together with the liberality of the Board of Trustees. The chemical and metallurgical students are now given laboratory practice, illustrating electrometallurgical principles. To the Museum of the Metallurgical Department have recently been added electric furnace ferro-alloys, made by the Heroult process, and electric furnace steels, made in the Kjellin induction furnace.

University of Wisconsin.—We have received Bulletin No. 104 of the University of Wisconsin, College of Letters and Science. The Summer Session and the Summer School for Artisans begin Monday, June 26, and close Friday, August 4. Among the summer courses there will be courses in general chemistry, qualitative analysis, quantitative analysis, chemical preparations and research work in organic chemistry (Prof. Lenher), and courses in electrochemistry, advanced electrochemistry, physical chemistry, advanced physical chemistry, research work in physical chemistry and electrochemistry, and a course in the preparation of typical organic compounds (Prof. Kahlenberg). Letters are to be addressed to the Registrar, W. D. Hiestand, University of Wisconsin, Madison, Wis.

A Course for Chemical Engineers at Columbia University.—In the current issue of the *School of Mines Quarterly*, Dr. Edmund H. Miller gives an account of a four-year course which is to be started at Columbia University for chemical engineers. The problem of the proper training of chemical engineers—in contradistinction to chemists—has repeatedly been discussed in our columns; we may refer the reader to Mr. J. B. Herreshoff's American Chemical Society paper and Mr. W. M. Sanders' communication, printed on pages 171 and 292 of our volume II, respectively. Columbia University is to be highly congratulated on the plan of starting a special course for the training of "a kind of chemist who is not being produced; a man who combines, with a solid knowledge of chemistry, considerable familiarity with both mechanical and electrical engineering; a man who is able to look at any proposition or process from the standpoint of the engineer as well as from that of the chemist." We will give a longer account of Dr. Miller's paper in our next issue. The course will go into effect in September, 1905; it is based on the same entrance requirements as those in the School of Mines and School of Engineering, and leads to the degree of chemical engineer.

Vanadium and Titanium.

By Hans Goldschmidt, Ph. D.

"Many are called, but few are chosen," may well be said of the metals which have been tried for alloys, particularly alloys for special steels. The steels must first be subjected to the most varied tests and refinements before a definite result can be spoken of, and before the properties of a new material are sufficiently understood with regard to its relations with iron. Not only the substance to be added is of importance, but also the proportion in which it is to be added, the other constituents present in the alloy, the impurities, and the treatment of the alloyed steel as finally produced.

It is easy to realize how difficult it is to obtain clear results, when the fact is borne in mind that small variations in the composition of the alloy—which can be detected only with difficulty, if at all—may produce great differences in the properties of the final product All the elements used in steel alloys, such as carbon, manganese, chromium, and nickel, as well as those which are present more or less accidentally and should be regarded as impurities, like sulphur, phosphorus, and silicon, have a good or bad influence upon the finished product according to the relative proportions in which they are present. Now, even with the few elements just mentioned, the mutual influences of the various amounts added are almost endless, and their investigation, even for these well-known substances, has taken place only within comparatively narrow limits; by the introduction of a new element the difficulty of the investigation is greatly increased, and to make the right choice is an "opus infiniti laboris."

When manufacturers of special steels have once arrived at satisfactory results, they must exercise the utmost care, not only to follow exactly the recipe in the manufacture, but to use always exactly the same starting materials. Manufacturers of special steels have often found that although they always followed exactly all points of the recipe, the finished product had not always the same properties. This occurs when a new raw material is used which had not been used before. Although it may fulfill all requirements of chemical anlysis, yet in practice the customary results are not obtained, for the reason that the uniformity of the new raw material is not sufficiently guaranteed. In this way the amount of scrap in special steel manufacture often becomes large beyond all proportions.

In this special point the manufacture of tool steels resembles the manufacture of a certain kind of other compounds which have nothing to do with the steel industry, but which can be made successfully only by following with absolute accuracy all details of a given recipe and by using always the same starting materials which have been found satisfactory. A very slight departure from the customary practice leads nearly always in this case to a failure. This case is the manufacture of artificial synthetic perfumes.

Moreover, it is not at all simple to follow a recipe for making special steels in spite of all imaginable precautions. This fact explains why only a few steel works have so far been able to furnish good and, above all, uniform special steels to their customers.

I do not need to say that I do not intend to speak in favor of following blindly a given recipe; it is clear that the recipe must be worked out on the basis of scientific principles, and of logically arranged experimental investigations. To give some suggestions for the difficult work in this field, is the purpose of this paper which the editor of this journal asked me to prepare. I hope to give some new information, supplementing what has already been published on vanadium and titanium—two elements which have been considered for some time as specially valuable for steel.

VANADIUM.

During the past few years vandium has been frequently tried in steel; indeed, it would not be any exaggeration to say that there is hardly a steel works of any importance in existence which has not experimented with this element, although its high price certainly cannot encourage the undertaking of experiments which are expensive enough in themselves. The high price of this substance, however, is only of relative importance, for the application of this element depends upon the results and on the required quantity of the element.

In both of these directions important progress appears to have been made recently, since notable improvements in steel have been successfully made with very small quantities of vanadium, so that the result attained seems to be by no means disproportionate to the cost.

In most of the earlier experiments ½ to 1 per cent of vanadium was added to the steel, but recently the quantity has been considerably reduced, and very important results have been obtained with 0.25 per cent of vanadium, and with even less. Prof. Arnold, of Sheffield (England), has carried out a series of scientific experiments on vanadium steels, and has had them published (see the note by A. F. Wiener, *Engineer*, July 1, 1904). These experiments may be reviewed here in the first place, so that we may draw further conclusions from them.

The most important observation that Prof. Arnold makes is a metallographic one: under the microscope the vanadium steel looks quite different from ordinary steel without vanadium. In ordinary steel (after the customary etching), two *distinctly* differentiated bodies appear under the microscope separated from one another, the one bright and the other dark, imbedded in the former and forming the true steel. The bright component is ferrite, the dark one pearlite. When vanadium is present, this distinct separation is considerably effaced and the appearance becomes more softened; that is to say, the pearlite, owing to the addition of vanadium, has partially dissolved in the principal constituent, the ferrite, and a more uniform structure has resulted. This observation holds when the amount of pearlite is small; that is to say, according to the German way of using the terms, it does not hold for steel* proper, but for a soft iron.

One microscopic test comes from a soft steel containing 0.22 per cent carbon; the limit of elasticity of this steel was 25.72 tons (40.51 kg. per square millimeter), its ultimate tensile strength was 30.64 tons (48.26 kilograms per square millimeter), and its elongation at rupture amounted to 33.5 per cent. The vanadium steel investigated micrographically contained 0.2 per cent of carbon and 0.27 per cent of vanadium. The limit of elasticity of the alloy was 37.4 tons (58.91 kilograms per square millimeter), its ultimate strength 47.08 tons (74.15 kilograms per square millimeter), and its elongation at rupture 22 per cent.

The following tables give some authentic results which have been obtained by Prof. Arnold by the addition of vanadium alloys to ordinary steel, and in combination with the other alloys which it has been customary to use heretofore. The rods which were investigated were circular in cross-section, three-quarters of an inch in diameter, and were forged from ingots of crucible steel and rolled.

Some months later a series of comparison experiments were carried out by Prof. Arnold, with the results given in Table 2.

TABLE 1.

	Elastic limit.		Tensile strength.		Elongation at rupture.	Reduction of area.
	tons per in.²	kgs. per mm.²	tons per in.²	kgs. per mm.²		
No. 682. Plain steel, about 0.25 C., 0.4 Mn.....	25.72	40.50	30.64	48.26	33.5	60.1
No. 684. Above steel plus 0.25 vanadium.....	37.40	58.90	47.08	74.15	22.0	51.4
No. 684. Plain steel plus 3.34 nickel.....	32.60	51.35	42.20	66.47	26.5	52.8
No. 685. Above nickel steel plus 0.25 vanadium..	50.28	79.19	68.16	107.35	17.0	36.3

TABLE 2.

	Elastic limit.		Tensile strength.		Elongation at rupture.	Reduction of area.
	tons per in.²	kgs. per mm.²	tons per in.²	kgs. per mm.²		
Plain steel, 0.25 carbon	18.0	28.35	27.0	42.53	38.0	65.0
Steel containing:						
0.25 C, 1 per cent W, 0.4 Mn.....	23.89	37.63	40.83	64.31	33.5	45.7
The same plus 0.25 Va.....	35.61	56.04	56.27	88.63	15.5	20.9
0.25 C, 1 per cent Ni, 0.4 Mn.....	24.94	39.28	37.58	59.19	39.5	46.1
The same plus 0.25 Va (No. 741).....	37.62	59.25	49.26	77.58	28.0	32.0
0.25 C, 1 per cent Cr, 0.4 Mn	26.48	41.71	41.15	64.81	35.5	55.2
The same plus 0.25 Va (No. 742)	39.76	62.62	55.08	86.75	26.0	53.0

The tables 3 and 4 show what a remarkable effect is obtained by introducing a very small quantity of vanadium into a high percentage nickel steel. The best results are those for a material containing 0.15 to 0.20 per cent carbon and 11.39 per cent nickel, as follows: Tensile strength, 88.8 tons (139.86 kgs. per square millimeter); elastic limit, 49.7 tons (76.70 kgs. per square millimeter); elongation, 12 per cent; contraction, 26 per cent. An addition of about 0.3 per cent of vanadium raised the elastic limit by 10 per cent, and the tensile strength by 12.5 tons (19.69 kgs. per square millimeter), or about 14 per cent above the highest figures which are obtained with nickel alone.

The introduction of ferro-vanadium into the steel does not give any trouble wherever the operations were conducted with care and intelligence. There is no loss of the valuable alloy, if

* By the term steel, we (in Germany) designate usually a rather high carbon content; with us the expression "weicher Stahl" (soft steel) corresponds to the French "acier dour," and the English soft steel is little used.

Table 3.

Rolled bars of nickel vanadium steel received from A. F. Wiener, made by W. Makin & Son, Sheffield.

Analysis.

Test piece:—	1 %	2 %	3 %
Carbon	0.141	0.135	0.121
Silicon	0.056	0.093	0.084
Sulphur	0.048	0.044	0.044
Phosphorus	0.044	0.038	0.034
Manganese	0.512	0.599	0.470
Nickel	9.630	9.290	8.660
Vanadium	0.290	0.162	0.120

it is added at the proper time, and care is taken that it is absorbed by the steel and not by the slag or scum. A perfectly homogeneous steel has been obtained in every case.

Thanks to the excellent new plant at University College, Sheffield, Professor Arnold has been able to make in the Siemens-Martin furnace a very remarkable casting, which contained 0.3 per cent carbon and 0.15 vanadium. After the 10-inch ingots had been hammered down to 3-inch billets and rolled to 1-inch bars, 42 tons (66.15 kg. per square millimeter) tensile strength, 22 tons (34.65 kgs. per square millimeter) elastic limit, 28 to 34 per cent elongation in 2 inches, and 55 per cent redurtion of area were recorded by the test. Moreover, this steel stood four complete twists when a straight 1-inch square bar tooled down to ⅞ inch round was submitted to a torsion test. The value of such a material is evident.

So much for the interesting experiments of Prof. Arnold. It is evident from the above experiments that especially the so-called soft steels are preferably alloyed with vanadium, and that further results may be expected in this direction. It is well known how important it is to get as high a durability as possible to meet the demands of modern industries; extra cost does not count, as long as it is not disproportionate to the result attained. We may instance the requirements of our automobile industry, which is demanding materials of higher and higher resistance, so as not to increase the weight any more; and the same is the case in ship-building.

Very remarkable experiments have been made recently in the producton of vanadium steel wire, containing about 0.25 per cent carbon, and the same percentage of vanadium. This is also a case of a soft steel.

But vanadium has also been used for especially hard steel, so-called tool steel. That vanadium is especially suitable for this purpose, is shown by the very nature of the element. Prof. Muthmann, of Munich, has recently succeeded in obtaining pure vanadium by a method of his own. He found that this pure vanadium is, perhaps, the hardest of all known metals, since it scratches even corundum. If, then, this hard vanadium could be alloyed and imbedded in the iron—the body of the alloy, the so-called ferrite—in such a manner that it is not more or less dissolved (as in the case of soft steel mentioned at the beginning of this article, according to microscopic tests), then it should be possible to attain a steel of extraordinary hardness. In this direction progress can be made only by means of experiments, which should depend, not only on chemical analyses, but also, above all things, upon the microscope.

Just at the present time it seems especially important to find a new alloy for hard tool steel, since that which is most used—tungsten—is difficult to obtain and subject to considerable variations of price. It is self-evident that a complete replacement of so important an element as tungsten for alloying for many purposes, cannot be spoken of; all that can be done is to find some other material for the preparation of hard steel, which, in the most favorable case, may form a partial substitute. Experiments have also been made regarding the simultaneous application of vanadium and tungsten, but hitherto the results have been indefinite, particularly when rather large quantities of tungsten were present in the alloy. But, of course, these experiments are not yet concluded.

Table 4.

Mechanical Tests.

A = original condition; B = annealed blood-red (610-648° C.); C = annealed cherry-red (740-760° C.); all cooled out in warm ashes.

Test piece.	1			2			3		
	A	B	C	A	B	C	A	B	C
Tensile strength—									
Tons per in.²	101.20	97.84	78.20	98.60	96.42	98.50	67.36	76.40	63.72
Kgs. per mm.²	159.39	154.10	123.17	155.30	151.86	155.14	106.09	120.33	100.36
Elastic limit—									
Tons per in.²	53.92	23.59	35.71	53.66	35.57	45.18	51.14	39.44	59.53
Kgs. per mm.²	84.92	37.15	56.24	84.51	56.02	71.16	80.55	62.12	62.26
Ratio, elastic limit to tensile strength	0.53	0.24	0.45	0.54	0.36	0.45	0.76	0.51	0.62
Elongation in % on 2 in.	11.0	12.0	20.0	10.0	7.0*	14.0	16.5	18.5	18.0
Contraction of area, %	35.5	15.4	36.0	25.4	7.1*	42.2	42.0	36.0	45.7

* Broke short. No. 2, as received, was probably chilled.

On the other hand, the simultaneous use of chromium and vanadium—even up to several per cent of chromium—appears to be advantageous. It is well known that chromium and tungsten are now generally applied together. Vanadium is not added to steel as such, but always as ferro-vanadium, generally with 25 per cent of vanadium.

The second part of this article, dealing with titanium, will be published in our next issue.

CORRESPONDENCE.

A Society Badge.

To the Editor of Electrochemical and Metallurgical Industry:

Sir:—The advisability of selecting a suitable pin or badge for the members of the American Electrochemical Society has already been discussed in your columns. I venture to call the attention of members to the badge distributed at the Boston meeting. It is attractive, and, with its electric furnace design, it is characteristic. It would be well for the Board of Directors to adopt it officially for general use. A. N. H.

New York City.

Boston Meeting of the American Electrochemical Society.

The seventh meeting of the American Electrochemical Society, held in Boston from April 25 to 27, was a most enjoyable social affair, and the local committee, with Dr. W. H. Walker as chairman and Dr. H. P. Talbot as secretary, as well as the authorities of Harvard University and of the Massachusetts Institute of Technology and other hosts of the Society deserve the highest praise for the true Bostonian spirit in which the Society was entertained. Considered purely from a professional point of view, the meeting turned out to be one of steadily increasing interest and of growing success, a remarkable climax coming on the last day; it was to be regretted that the time was then somewhat limited. Thus, the Convention was in every respect a very decided success.

At the business meeting, held on Wednesday morning, the reports of the secretary and treasurer were read and accepted; they show that the Society is in a very good financial condition. The proposed amendment to the constitution, by which the time of election of officers is slightly changed, was accepted. The result of the annual election of officers was announced in the Thursday meeting, and is as follows: President, Dr. Wilder D. Bancroft, of Cornell University; vice-presidents, Messrs. Carl Hering, Louis Kahlenberg, E. F. Roeber; managers, Messrs. C. A. Doremus, C. P. Townsend, W. R. Whitney; secretary, Mr. S. S. Sadtler; treasurer, Mr. P. G. Salom.

The three forenoons of April 25, 26, 27, were devoted to the reading and discussion of papers; a full report will be found below.

After the morning session of April 25, a reception was held by President Pritchett, of the Massachusetts Institute, at the Technology Club, followed by a lunch, tendered by the Institute. The afternoon was devoted to an excursion to the General Electric Company's plant at Lynn. Professor Elihu Thomson and Mr. Richard Fleming showed the visitors, with great courtesy, through the works, and the occasion was highly enjoyed. The visitors had an opportunity of seeing large and small machinery in the process of manufacture. We may only mention steam turbines and electrical measuring instruments, while a highly appreciated feature of the visit was a practical demonstration of the great variety of the spectra of various types of electric light (incandescent lamp, Nernst lamp, arc lamp, mercury vapor lamp, etc.) by showing the remarkably different color effects which these different sources of light produce in the same colored fabrics.

On the evening of the same day, after Dr. H. S. Carhart's presidential address, a smoker was held in the Palm Garden of the Hotel Lenox; it was conducted by Dr. W. H. Walker, somewhat in form of a German beer "commers," and was very "gemütlich," the tunes of the Prince of Pilsen alternating impartially with those of the Commersbuch.

After the close of the Wednesday morning session a reception was held at Harvard Union by President Eliot, of Harvard University, who made a felicitous little speech, in which he emphasized the importance of electrochemistry; it is in the borderland of sciences that the most radical achievements are often obtained. He sketched the ideals and tendencies determining the development of higher scientific and technical education in the United States. A lunch was then taken which was tendered by Harvard University.

For the afternoon two parties were made up. One visited the buildings of Harvard University, under the leadership of the professors of the various institutions, while the other party made an excursion to the works of the New England Gas & Coke Co., at Everett (Otto-Hoffmann system), where the visitors were shown with great courtesy through the different departments of the works. The plant uses normally per day 1,700 tons of coal, which are brought by ship directly to the works from Nova Scotia. A storage of coal, sufficient for three weeks' work, is possible.

On the evening of the same day a delightful banquet was held at the Hotel Lenox; Dr. A. E. Kennelly distinguished himself as toastmaster and introduced the speakers with humorous and pointed remarks. Dr. H. S. Carhart, as the retiring president, reversed an old joke of Dr. Wiley, who, at a former banquet, had tried to connect the initials of the Society —A. E. S.—through the Latin word *aes* with certain tendencies. Dr. Carhart reversed the order of the initials, and compared the Society and electrochemistry in general with a *sea* of unlimited possibilities. Dr. J. W. Richards took up this theme; after having referred to the formation of a Society in Philadelphia, he sketched the splendid future which lies before electrochemical and metallurgical industries. Dr. H. W. Wiley made one of his characteristic and charming speeches, full of humor and wit—at the expense of others as well as himself. He had in the beginning been opposed to the formation of the Society, but when it was founded he came in quickly, and was not sorry for it. Chemistry is a science of such fundamental and vast importance that it needs various societies to cover the ground thoroughly. Professor W. S. Franklin spoke of the necessity of utilizing forms of energy now wasted, and told a story of a man looking at Niagara Falls and saying: "What a waste!" But he was not "one of those electrochemists," he was a milkman.

After the Thursday session a lunch was tendered again at the Technology Club by the Massachusetts Institute. The afternoon was devoted to visits to the various buildings and laboratories of the Massachusetts Institute.

TUESDAY SESSION.

The first session was held at Lowell Hall of the Massachusetts Institute of Technology. President H. S. Carhart called the meeting to order.

REVERSIBLE AND IRREVERSIBLE ELECTROLYTIC POLARIZATION.

A paper on this subject, by Professor W. S. FRANKLIN and Mr. L. A. FREUDENBERGER, was presented by Professor Franklin.

The authors begin with some general remarks on the essential suppositions made in applying the principles of thermodynamics to actual phenomena, and then pass over to the subject of electrolysis. In a study of the phenomena of electrolysis, a thing of first importance is to determine, within the limits of experimental precision, whether the process approaches complete reversibility as it is made to take place more and more slowly. The great difficulty encountered here, aside from the difficulty of approaching a limit by experimentation, is that subsidiary actions take place during electrolysis (diffusion, local action, etc.). The ordinary point of view is to consider that those subsidiary actions may be legitimately treated as actions which are independent of the main phenomenon of the deposition and discharge of the ions on the electrodes by the current.

The authors refer to Caspari's investigation of the cathode polarization in the electrolysis of sulphuric acid when the current is barely large enough to produce visible generation of hydrogen. Caspari found that cathodes of the different metals show characteristic excess-voltages (Überspannungen), *i. e.*, the development of hydrogen at the cathode requires a voltage in excess of the value corresponding to the reversible liberation of hydrogen. This excess-voltage, or over-voltage, is nearly zero on spongy platinum, and about three-quarters of a

volt on zinc and on pure mercury. Ostwald and Bredig have suggested explanations according to which the over-voltage would be due to fundamentally reversible processes immediately accompanying electrolysis proper, while only independent actions, really subsequent to the deposition, are irreversible.

The authors then take up the discussion of the reversibility or irreversibility of electrolytic polarization by the following method. The work spent in forcing a current through an electrolytic cell consists mainly of three parts:

(*a*) The work which appears as heat throughout the electrolyte. The rate at which work is so spent—that is, the rate of generation of heat throughout the electrolyte, is accurately proportional to the square of the current, according to Joule's law.

(*b*) The work which appears as heat at the electrodes on account of the irreversible processes which take place as the ions are deposited. The rate at which work so expended is a function of the current, and it may be represented by F (i).

(*c*) The chemical decomposition of the electrolyte by the current requires work, and the reaction of the liberated ions upon the solvent or upon the electrodes is often a source of energy. The net rate of expenditure of energy in these ways is proportional to the current—it may be either positive or negative. Work gained or spent in an electrolytic cell on account of thermoelectromotive forces or on account of electromotive forces at places where the electrolyte changes in concentration, or in composition may be included in this item (c).

Thus, if a current *i* passes through an electrolytic cell, and if the e. m. f. is E, the power is

$$Ei = Ri^2 + F(i) + e\,i$$

where *e* is the proportionality constant mentioned above in item (*c*). From this follows directly the e. m. f. equation,

$$E = Ri + f(i) + e$$

so that the total e. m. f. E may be considered as the sum of three distinct items. The first one, *Ri*, is the e. m. f. consumed by ohmic resistance. The sum of the two others (or rather its negative value) is the e. m. f. of polarization. Now, it is at once seen that the polarization consists of two parts: one, the reversible polarization, *e*, which is not a function of the current; the other f (*i*), the irreversible polarization which is a function of the current.

By this method it is, of course, directly possible to separate experimentally the reversible from the irreversible polarization, and to decide the fundamental question, whether there exists an irreversible polarization. This was the object of the experiments of the authors. The method is to cause the current to vary, thus separating *Ri* and f (*i*) from *e*, so that f (*i*) becomes known when *Ri* has been determined. The difficulty encountered in the realization of this method is that *e* is to a certain extent a function of the coulombs passed, because of local concentration changes of the electrolyte, because of progressive changes in the character of the surface layers of the electrodes, and because of temperature changes due to continued flow of current. However, the authors believe that by their arrangement of the experiments they eliminated these disturbing factors. They experimented with copper sulphate solutions and copper electrodes.

The results were plotted by the authors in form of curves, which were shown by Professor Franklin on Wednesday. The authors determined the irreversible polarization f (*i*), but did not separate it into anode and cathode parts. The results show distinctly the existence of irreversible polarization. For particulars the reader must be referred to the full paper, which will be printed in the Transactions of the Society.

In the discussion which followed, Mr. Carl Hering spoke at length on the use and misuse of the term polarization. He also referred to the development of oxygen and hydrogen by electrolysis of water, and distinguished two processes; first, the disintegration of chemical bonds; second, the expansion of gases against atmospheric pressure. He asked where the energy for the second process comes from, and expressed the opinion that it cannot come from the current.

Aluminium Electrolytic Condenser.

A paper on this subject, presented by Mr. Clarence Irving Zimmerman, was a continuation of his former paper on the same subject (our Vol. II, p. 182). The author first explained the action of an aluminium electrolytic condenser by an hydraulic analogy with a combination of membranes and valves. He then gave the results of experiments in which the resistance, dielectric strength and inductivity of the film on the aluminium anode were determined, and found to be as high, or higher, than in ordinary dielectrics. The resistance in one instance is shown to be about 10^{11} ohms per cubic centimeter. A value of about 5,000,000 volts per centimeter is obtained for the dielectric strength. A value of about 14.6 is obtained for the inductivity (specific inductive capacity or dielectric constant).

The author then gave a graphical analysis of the cell losses. They consist of (1) film losses, (2) C^2R losses, and (3) electrolytic decomposition losses, while the film losses (1) consist

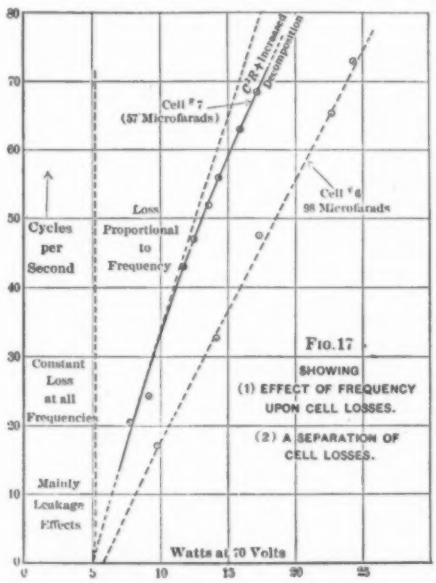


Fig. 17 showing

FIG. 1.—LOSSES IN ELECTROLYTIC CONDENSER.

of (a) leakage through film, and (b) losses proportional to the frequency. The latter are in general larger than the other losses in the cell, and are of a nature not clearly understood. A crude graphical representation of these losses is given in Fig. 1, where there is plotted a curve between watts and frequency. The observations were made upon two cells in which the electrolyte consisted of an aqueous solution of commercial borax. All the losses were increased considerably by this impure electrolyte.

The condenser-charging current varies in proportion to the frequency, when the impressed pressure is kept constant. At low frequencies, however, the watt consumption shows a slight variation from a straight line law, due to the predominating effect of the leakage current.

The theoretical relation of the alternating pressure, *e*, impressed upon the cell terminals to the unidirectional pressure between the electrolyte and a point neutral to the alternating pressure is equal to the impressed pressure *e*, divided by $\sqrt{2}$. The actual values obtained are smaller than these, due chiefly to the imperfect symmetry and partially to the cell resistance, to film leakage, and to polarization pressures.

Fig. 2 shows the relations existing in a cell each of whose

plates had a capacity of 114 microfarads. The electrolyte consisted of a saturated solution of borax with a small amount of glycerine added. The method of obtaining these pressure relations is shown in Fig. 3. The alternating-current 60-cycle pressure was varied from 140 volts to a fraction of a volt. The curve is practically a straight line above 10 volts alternating pressure. Below this point, the unidirectional pressures keep close to the zero value, owing to the slight asymmetrical effect of the film at such low values and to the polarization pressures between the aluminium and the carbon. If the straight part of this curve be projected until it crosses the horizontal line representing the zero of alternating pressure, the undirectional value is 4½ volts. Part of this pressure is probably produced by the chain aluminium - electrolyte - carbon. The dotted line in the diagram represents the theoretical relation based upon the assumption that there is perfect symmetry, that there are no polarization pressures, and that the losses in the cell are zero. These pressure relations do not materially vary with any small change in frequency, and since such a cell can be easily set up, this scheme may be used for the purpose of calibrating alternating-pressure instruments where extreme accuracy is not desired. It is not necessary to use the zero method of Fig. 3 for the purpose of calibration. It is merely necessary to connect the alternating-current instruments across the cell terminals and the direct-current

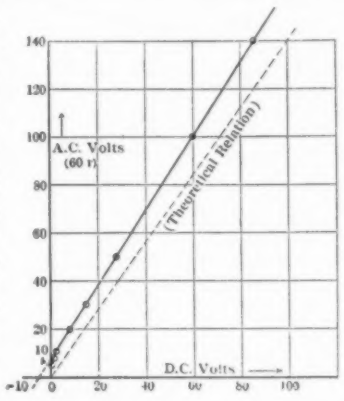


FIG. 2.—RELATION BETWEEN DIRECT AND ALTERNATING-CURRENT VOLTAGE.

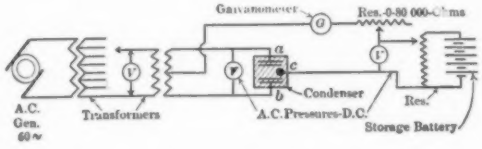


FIG. 3.—ARRANGEMENT OF EXPERIMENTS.

instruments between the carbon (electrolyte) and one of the aluminium electrodes.

The author then discussed what he calls "unsymmetrical condensers," *i. e.*, aluminium condensers having two electrodes with different electrostatic capacities. Their behavior was fully discussed and analyzed graphically and mathematically. Oscillograph curves were shown of the different pressures. It was shown that the unidirectional pressures across each electrode may be considerably greater than the impressed pressure. The behavior of the cell on alternating-current circuit is, notwithstanding its peculiarities, similar to two tinfoil condensers in series. The "equivalent" capacity is $\frac{c_1 c_2}{c_1 + c_2}$ where c_1 and c_2 are the electrostatic capacities of the films on the two electrodes. Two-phase and three-phase condensers were also discussed, and the three-phase condenser pressures were shown diagrammatically. The paper was illustrated by a number of interesting experiments.

The paper was briefly discussed in a communicated note of Mr. W. R. Mott, who made some complimentary remarks on Zimmerman's work, but pointed out that further and quite difficult investigations are necessary to determine the absolute figures for all the properties of the film.

ECONOMIC TEMPERATURES OF COPPER-REFINING SOLUTIONS.

A paper on this subject, by Professor CHARLES F. BURGESS, was then presented, in the absence of the author, by Dr. M. deK. Thompson. It referred to the investigation of Bancroft (our Vol. I, pp. 484 and 584), who, from experiments made by him, had concluded that a greater economy can be effected if the solutions are run at a higher temperature than has been commonly adopted by copper refineries. In the present paper Professor Burgess shows that Bancroft's conclusion is open to objections.

The pressure between the two electrodes of a copper-refining tank is the sum of two quantities—the polarization pressure and the drop caused by the current flowing through the electrolyte. The former is small and may be considered as practically constant for a given solution, being influenced very slightly by the temperature. The IR drop through the electrolyte varies, however, in a marked degree with change of temperature, and it is this variation which causes the falling off in applied pressure necessary to pass a given current through the cell as the temperature rises.

Professor Bancroft experimented with copper electrodes 1 centimeter apart, in a solution containing 16 per cent copper sulphate crystals and 9 per cent free acid, with a current density of 3.5 amperes per square decimeter, and found that the pressure at 70° is less than half that required at 20° for the same current, and consequently that the cost of the power is less than one-half. He stated that "by expressing voltage in terms of the voltage at 20° the effect of the distance between the plates is eliminated," and that "the percentage variations hold for any set of plates in the same solution."

Professor Burgess objects that this assumption, which served as a basis upon which various conclusions were drawn, would undoubtedly be correct if we are concerned only with the specific resistance of the electrolyte itself, but since it is the virtual resistance between the electrodes that is involved, the assumption is not justified.

The resistance of the cell includes the resistance between the electrode surfaces and the electrolyte, and the resistance of the electrolyte itself. The former is of considerable magnitude in comparison with the latter when the electrodes are close together, and of much less relative magnitude when a considerable column of electrolyte intervenes. The temperature coefficient at the electrode surface resistance is much greater than the temperature coefficient of the electrolyte, and unless these separate resistances and their corresponding temperature coefficients be known, it is impossible to calculate the temperature coefficient of the complete cell with electrodes 5 centimeters apart from measurements on electrodes 1 centimeter apart.

The author gives results of measurements which show clearly that the lowering of voltage is not proportional to the increase of temperature regardless of the distance between the plates, but that on the other hand the temperature effect is far more marked when the electrodes are close together than when they are far apart. In other words, the apparent temperature coefficient is dependent upon the distance between electrodes, being greatest when the electrodes are close together.

We are not, therefore, warranted in saying that the most economical temperature in a cell with the plates 1 centimeter apart is the most economical for a cell with the plates one-half inch or 1½ inches apart, as in the series and multiple refining systems respectively.

The author then discusses what Gore called the "transfer resistance" from electrode to electrolyte, and points out that if there exists a resistance at the electrode surface apart from the resistance of the electrolyte itself, of such nature that it has a great temperature coefficient, we have an explanation of the

dependence of the apparent temperature coefficient of an electrolyte upon the distance between the electrodes, the reduction of the "transfer resistance" producing a greater proportion of the total change when the electrodes are close together than when farther separated. Professor Burgess describes a series of experiments which appear to show that in a neutral copper sulphate solution the change of resistance with temperature is due almost entirely to the temperature coefficient of the electrolyte itself, while there are distinct electrode effects in case the electrolyte contains free acid. Further experiments were made by tracing the fall of potential from the anode to the cathode by means of a normal calomel electrode. There is a fall of potential at the two electrodes equal to about 0.2 volt, the cathode contributing to this effect a considerably greater part than the anode. On the other hand, the polarization, as measured by the voltmeter upon interruption of the current, is only 0.02 volt. Against the assumption that this method might not give the total polarization, Professor Burgess remarks that it would be apparently out of the question to assume a polarization of about 0.2 volt.

Neither does the drop of potential appear to be due to changes of composition of the solution as a result of electrolysis, since in this case the effect would be materially decreased by agitation of the electrolyte, while in reality the agitation of the solution had very little influence on this surface resistance. It is also shown that the electrode effect is not a result of electrolytic products, since it also accompanies the flow of alternating current of such small value as to make the accumulation of electrolytic products impossible.

In the discussion which followed, Professor W. S. Franklin said that a genuine polarization of 0.2 volt is not out of question; he found in his experiments an actual polarization of 0.1 volt with quite small current densities. He also showed how some of the results of Burgess may be used to decide the question of reversible and irreversible polarization. Messrs. Lidbury, Hering and Thompson also participated in the discussion. Mr. Lawrence Addicks had communicated a note in which he said that while Professor Burgess' results are very interesting, he has not solved the conundrum; there is no doubt as to the existence of a transfer resistance, but we don't know its nature.

A Diaphragm Cell for Electrolysis of Sodium Chloride Solutions.

An interesting paper, by Mr. Clinton Paul Townsend, describing his new diaphragm cell (see also page 73 of our March issue) was then presented.

The electrolysis of sodium chloride solutions with insoluble anodes under conditions which permit the liberated sodium to decompose water may readily become a complex operation by reason of the variety of secondary products which may result. If it be desired to isolate with substantial completeness the chlorine which is the primary anode product from the sodium hydroxide, which is the secondary cathode product, it is necessary, first, to prevent the mechanical mingling of anode and cathode solutions, and, second, to prevent the sodium hydroxide formed at the cathode from participating in the electrolysis. The first of these conditions is readily secured by a variety of means, but the second has heretofore proven impossible of complete accomplishment.

As regards the mixing of the solutions, both anolyte and catholyte are necessarily in more or less violent motion, due to gas evolution. It is evident, however, that any device or disposition of parts which will insure a quiescent region of contact between these solutions will avoid their mixing. This is easily accomplished in the various gravity cells by depending partial partitions or bells which provide a quiet lower stratum of electrolyte; it is as readily accomplished by a diaphragm, say, of thin asbestos paper, the interstices of which provide the necessary quiescent layer.

A diaphragm of this character does not for practical purposes check the movement of the caustic by diffusion into the anode chamber, or the migration of the hydroxyl ions toward the anode if the conditions be such that the hydroxid takes part in the electrolysis. The diaphragm cell and the gravity cell may, therefore, be expected to work at ampere efficiencies of the same general order and the published data seem to bear out this conclusion. This ampere efficiency is understood to lie in practice between 75 and 85 per cent. These figures represent current losses which are in themselves serious; the losses are doubly serious in practice because they are largely represented by hypochlorite and chlorate in the anode liquor, in the presence of which graphite anodes rapidly disintegrate, yielding an impalpable carbon dust which will soon put a diaphragm cell out of commission. The use of platinum anodes is a possible alternative, but a costly one for cells equipped at the present time, and, moreover, they do not reduce the power losses; this latter objection holds against the practice of decomposing the hypochlorite in the anode compartment by addition of hydrochloric acid.

The statement is frequently made that if the rate of flow toward the cathode be rapid enough to compensate the migration velocity of the hydoxyl ion the ampere efficiency should be 100 per cent; this proposition applies to gravity and diaphragm cells alike, and is the basis of some of the earliest forms. As a matter of fact, however, the solution which flows from anode to cathode carries a very considerable percentage of dissolved chlorine, and practical experience has shown that long before such rate of flow has been reached that hypochlorite and chlorate disappear from the region of the anode, the losses by the action of this chlorine on the cathode products becomes serious. Under such extreme conditions the moving liquid can dissolve all of the chlorine and the caustic efficiency of the cell will fall to zero.

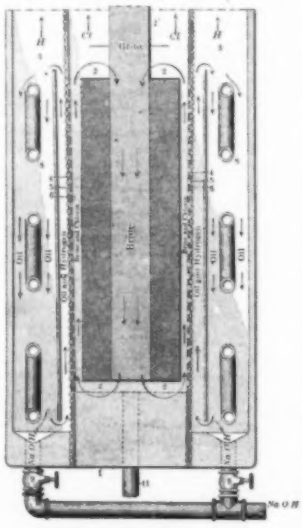


FIG. 4.—DIAPHRAGM CELL.

The instantaneous removal of the caustic, as formed from the electrolytic field and from contact with the anode liquor, would mean the avoidance of all difficulties which arise from the presence of hydroxyl ions in the anode compartment. The chlorinated liquor would then remain free from hypochlorite or chlorate; graphite anodes should be substantially permanent, and the evolved chlorine should be pure. This result is nearly and, perhaps, fully accomplished by a cell, the lower portion of which is somewhat diagrammatically illustrated in Fig. 4 in transverse vertical section. The experimental cell has a central brine compartment 1, having cement walls and carrying spaced anodes 2, 2. These anodes, as well as their conductors 2', are of Acheson graphite. The lateral compartments 3, 3, are of iron, and in operation are filled with a mineral oil which completely submerges one face—the back—of the wire-net cathode 4. The active face of this cathode is in contact with the diaphragm 5, which is, of course, quite permeable to the clorinated anode liquor. The diaphragm is supported on the side toward the anode by a pervious layer, 6, of good mechanical strength; 7, 7, are steel plates adjacent and parallel to the cathodes and submerged in the oil; 8, are

pipes for maintaining the temperature of the oil, and thereby of the electrolyte, 9, 10, is the caustic outflow, and 11 the brine inlet.

The chlorine liberated at the anode faces rises through the narrow channels between the anodes and the diaphragms, and acts in a manner similar to an air-lift to induce through this channel a flow of electrolyte in the direction indicated by the arrows. The rate of this flow, the purpose of which is to wash the diaphragm and to prevent any fall of concentration around the anode, depends upon the current density, and under proper conditions attains several feet per second. Uniform concentration is maintained.

As stated, the inactive face of the pervious cathode is immersed in a liquid which is immiscible with the caustic solution and chemically inert toward it. The hydrogen which is liberated at the cathode escapes into the oil, and thence upwardly through the narrow channel afforded by the plate 7, and sets the body of oil in extremely rapid circulation. At high-current densities, in excess of 100 amperes per square foot of electrode surface, the rapidity of this circulation is quite striking.

The oil acts as a seal to prevent carbonating the caustic, as a support for the diaphragm, which may be of extreme thinness, and by its partially balancing hydrostatic pressure it tends to equalize the flow of electrolyte from top to bottom of the diaphragm. But its chief function relates to the quick removal of the caustic from the electrolytic field. Caustic solution does not adhere to surfaces wetted with oil, and, therefore, the caustic does not accumulate in the cathode nor flow down the cathode in proximity to the chlorinated liquor; instead, it is projected by the escaping hydrogen into the oil in the form of minute globules and deposited under the oil at the outlet of the cell.

If this removal of the caustic were instantaneous neither hypochlorite nor chlorate, derived from this source, would be found in the anode liquor. The data following represent the composition of the anode liquor in a cell having 9 square feet of active anode surface. The experimental run was continuous from August 14 to September 7, the anode liquor being sampled daily.

Date	Amp	Cl Grams per Liter	ClO Grams per Liter	ClO_3 Grams per Liter	
Aug. 14	1000	....	....	....	Start 3.30 p. m.
" 15	"	0.57	0.084	0.424	
" 16	"	0.14	0.154	0.0	Analy'd Aug. 18
" 17	"	0.26	0.0	0.0	Analy'd Aug. 18
" 18	"	0.35	0.105	0.0	
" 19	"	0.64	0.07	0.0	
" 20	"	0.355	0.091	0.0	
" 21	"	0.41	0.091	0.0	Analy'd Aug. 23
" 22	"	0.28	0.028	0.0	Analy'd Aug. 23
" 23	"	0.50	0.133	0.0	
" 24	"	0.53	0.091	0.0	
" 25	"	0.55	0.091	0.0	
" 26 a. m.	1200	1.02	0.154	0.368	
" 26 p. m.	"	1.03	0.21	0.440	
" 27	"	0.50	0.077	0.088	
" 28	"	0.43	0.0	0.0	
" 29	"	0.46	0.133	0.0	
" 30	"	0.57	0.063	0.0	
" 31	"	0.57	0.119	0.0	
Sept. 1	"	0.51	0.119	0.0	
" 2	"	1.065	0.049	0.088	Analy'd Sept. 12
" 3	"	0.19	0.119	0.224	Analy'd Sept. 15
" 4	"	0.46	0.0	0.072	Analy'd Sept. 15
" 5	"	0.28	0.0	0.104	Analy'd Sept. 15
" 6	"	0.28	0.028	0.128	Analy'd Sept. 15
" 7	"	0.38	0.07	0.144	Analy'd Sept. 12

The samples of Sept. 2-7, inclusive, were analyzed after standing for several days in bottles exposed to the light. The traces of chlorate shown in these particular analyses were in all probability produced during this period.

During the run the cement walls of the anode compartment were attacked to a considerable extent, some calcium and magnesium appearing in solution and hydrated silica in suspension in the anode liquor. It is by no means certain that the persistent traces of hypochlorite shown by the analyses, never rising to 2/100 per cent and seldom entirely disappearing, existed as the sodium salt; it is quite probable that the hypochlorite is attributable chiefly to the action of the chlorine on the cement, more particularly because it reaches its maxima at the very beginning of the run, and whenever the wash of the anode liquor is increased by raising the current density.

The above results should correspond to substantially pure chlorine. The samples collected showed 99.7 to 99.8 per cent Cl, subject to a correction of unknown magnitude for the aeration of the anode liquor which, under the particular circumstances, was unavoidable. The effect of this and other errors affecting the analysis would be to increase the above chlorine value.

Caustic efficiency: The anode liquor carried about 0.55 grams per liter of dissolved chlorine. This is the solution which oxidizes the cathodic deposit of sodium, for, as will be apparent, the cell has no distinct cathode electrolyte. The dissolved chlorine in a volume of solution corresponding to the actual outflow through the cathode would correspond to a loss of caustic amounting to about 0.4 per cent of the theoretical yield for 1000 amperes. We should, therefore, expect a caustic efficiency not to exceed 99.6 per cent of theory. All caustic solution produced throughout the run was weighed and analyzed, but the errors incident to sampling and current measurement were sufficient to mask this presumably necessary loss, the apparent caustic efficiency being in slight excess of the expected result.

Mr. Townsend then referred to his article published in ELECTROCHEMICAL INDUSTRY for December, 1902, in which he gave some data as to the sodium chloride content of certain electrolytic caustic soda lyes. At that time it was not considered advisable to describe the cell other than by the statement then made that "it was provided with a thin permeable diaphragm, adapted to restrain and equalize the flow of the electrolyte, and a cathode whose form fitted it to serve as a surface for the rapid discharge of the cathode products." This possibly somewhat inadequate description of the present cell gave rise to a misconception, which led to a criticism[1] of the article on the ground that two essential conditions had been overlooked, to wit: the concentration changes which take place around the electrodes when sodium chloride solution is electrolyzed in the anode and cathode compartments of a diaphragm cell, and the migration velocities of the hydroxyl ions when the formed caustic participates in the electrolysis. Mr. Townsend replies that it will now be clear that the reasons for not considering these factors were, first, that the caustic is formed by oxidation of sodium in a homogeneous chloride solution maintained at constant concentration, and, second, that the "rapid discharge of the cathode products" is sufficient to guard against the entry of the caustic into the electrolytic field.

In the discussion, Dr. J. W. Richards asked what prevents the sodium chloride from passing into the caustic, and Mr. Townsend replied that there is no means of preventing that. But the separation of the chloride from the caustic can be easily effected by evaporation until the specific gravity is about 50° Baume.

CONDUCTION IN ELECTROLYTES.

A paper on this subject was presented by Professor JOSEPH W. RICHARDS, who spoke especially on the conduction in molten and solid electrolytes. He emphasized that if the conductivity of a fused or solid salt is determined as function

[1] Trans. Amer. Electrochemical Society, Vol. III, p. 177.

of the temperature, there is no break in this curve at the melting point, and from the curve alone it would be impossible to say when the electrolyte begins to set (The conductivity becomes zero only when crystals begin to form.) The author concludes that whatever the nature of conductivity of salts in the liquid state, the conductivity in the solid state must be necessarily of the same nature.

Solid sodium carbonate shows a measurable conductivity at 600° below the melting point. Reference was also made to the recent work of Haber and Tolloczko (our March issue, p. 99).

The author then develops the following hypothesis: Electrolytic conduction in a solid salt seems to come into existence when the possibility of the formation of new phases at the two electrodes is caused by the increase in temperature. The migration of the ions is then the consequence of the formation of new phases. The acid phase produced at the anode, and the basic phase produced at the cathode diffuse against each other; and this diffusion of the new phases accounts for the migration of the ions. Thus the phenomenon of electrolysis is dissolved by the author into the creation of new phases and their diffusion.

In the discussion which followed, Professor H. S. Carhart thought that this theory does not explain how the passage of the current does take place in the first place. Professor W. S. Franklin said that diffusion undoubtedly occurs, but is something subsequent to electrolysis proper. Dr. W. R. Whitney spoke of the danger of confusing the electrolytic reactions at the electrodes with the conduction through the electrolyte. Dr. Theo. W. Richards thought the hypothesis would not account for such cases as electrolysis of silver nitrate between silver electrodes. Dr. Joseph W. Richards replied he did not know just how the electric current passes through a salt, but he expressed the conviction that electric conduction is essentially of the same nature in metals, fused salts and solid salts.

Mr. C. I. Zimmerman gave some very interesting notes on the conduction of Nernst lamp filaments. There is direct evidence that there is electrolysis, to a certain extent, while other phenomena show a distinct analogy with gaseous conduction, particles being thrown off from the negative electrode. Iron, gold, etc. (when used as terminals through which the current is introduced), travel against the direction of the current. There is also strong evidence of thermoelectric effects at the junctions. If platinum is used at the positive terminal, and silver at the negative terminal, the platinum may become white hot, while the silver does not melt, in spite of its much lower melting point; the reason is that at the silver junction heat is absorbed by the thermoelectric effect.

Absolute Potentials.

Dr. H. M. Goodwin then presented a paper on Billitzer's method of determining absolute potentials. It will be remembered that Billitzer has found a value for the absolute potential of the calomel electrode which is different by 0.7 volt from the usual value (0.57 volt) determined by the drop electrode. It was, therefore, of importance to repeat Billitzer's experiments, but this is difficult, since Billitzer, in the description of his experiments, did not state the concentration of the solutions used. Dr. Goodwin repeated, as far as possible, those experiments in which zero deflection of a suspended metallic particle is taken as the criterion for the non-existence of an electric double layer. But he was able to get similar results as Billitzer in a general qualitative way only in some cases. In certain liquids no check whatever could be obtained. Another method of Billitzer, in which the migration of colloids was taken as indicator, was tested by Dr. Blake, who found that he could make the colloids travel at will in either direction, according to the amount of gelatine present. Under these circumstances it would be premature to give up the accepted value of the absolute potential of the calomel electrode.

Edison Storage Battery.

Mr. M. deK. Thompson presented a paper on an experimental investigation which has been carried out in the Massachusetts Institute of Technology on the Edison nickel-iron storage battery. The results of this investigation were given by lantern slides, and referred mainly to measurements of the single potentials during charging and discharging. Some of these results were very interesting. For instance, if the concentration of the solution is varied, the discharge of the Fe electrode is little affected as long as the concentration is above a certain value. But this is changed for smaller concentrations. Thus, in a 5 per cent solution the discharge curve of the iron electrode is very different from that in a 20 per cent solution. A more detailed report of the paper must be deferred until the paper appears in full in the Transactions of the Society.

Tuesday Evening Session and Presidential Address.

At a special evening session, in Lowell Hall of the Massachusetts Institute, a very fine exhibit of various chemical and electrochemical apparatus, by Messrs. Eimer & Amend, of New York City, was shown and explained by Dr. W. H. Walker. The exhibit covered the Wanner pyrometer, apparatus made from fused quartz, materials for electric furnaces, and a large collection of electric furnaces for many different kinds of work. Among the latter furnaces, using the new resistance material, Kryptol, were especially well represented. These furnaces were exhibited with the current switched on, and the ease of manipulating them was explained.

Then followed the main feature of the evening session—the address of the retiring president, Dr. Henry S. Carhart, who spoke in a most interesting manner on the development which the theories of electrolysis have undergone during the last hundred years. He gave a great many details on the early history (about 1800) of the theory of electrolysis, offered a quite enthusiastic account of Grotthus' researches, and covered successively the work of Clausius, Hittorf, Kohlrausch, Arrhenius and Van't Hoff. The speaker then passed over to J. J. Thomson's recent researches on electric currents through gases, and expressed the opinion that we have not yet the ultimate truth. We will, however, get at it, though "we need not prophesy—we need only to work and wait."

It is impossible to do justice to Dr. Carhart's address in a short abstract, but this address will be most interesting reading when published in full in the Transactions.

Wednesday Session.

At this session, which was held in Peirce Hall of Harvard University, the annual reports of the secretary and treasurer were presented and accepted. The reading and discussion of papers followed.

Chromium and the Electrolysis of Chromic Acid.

A paper by Messrs. H. R. Carveth and B. E. Curry on this subject was then read by Dr. Carveth. The paper is extremely interesting, since the deposition of chromium from a chromic acid solution appeared a priori not very promising. There has been in the past a great diversity of opinion on this subject. The main results of the paper are as follows:

In the study of the cathode reactions at least three, but more probably four or more, different stages of oxidation are met. This means that in the various solutions there are chromium ions with four different valencies.

In regard to the constitution of chromic acid solutions the following facts must be noted: (a) The study of the equilibrium relations point to the existence of free CrO_3—a radical composed of a conductor and a non-conductor of electricity. So far as the authors are aware no compound of such a combination is known which, conducting the current in aqueous solution, is not by the supporters of the theory of electrolytic dissociation supposed to be dissociated into ions. (b) Chrom-

ium as anode may dissolve to form CrO_3. If dissolving to form an ion this will be hexavalent. There is a continuous passage from the conditions where it dissolves divalent (and everyone concedes its ionization, because a salt is formed) to the conditions where it dissolves hexavalent (where ionization has not been conceded, because an acid was formed). (c) Chromium may be deposited from chromic acid after a definite decomposition voltage has been reached.

This evidence, therefore, makes it seem very probable that in chromic acid there exists a number of hexavalent chromium cations in equilibrium with many other ions, and that chromium in chromic acid may be considered a reversible electrode.

The main part of the work of Geuther (Liebig's Annalen, Vol. 99, p. 314, 1856) is correct. Metallic chromium is deposited in the electrolysis of solution of chromic acid, but this requires a high-current density, which in this case is synonymous with a high-decomposition voltage. For example, using platinum wires as electrodes, Geuther used currents of from 0.07 to 0.35 amperes—very great densities, probably higher than the authors have used. On comparing with their own results the very great percentage reductions and the high metal depositions which he obtained, they conclude that his acid must have been impure. The oxygen excess which he found at the anode, and which enabled Buff to criticise him severely, the authors have never been able to find; his admission that his tangent galvanometer was wrong probably explains this. After the decomposition point is reached, the efficiency of metal deposition and the reduction of the acid go hand in hand; a chromium chromate is probably formed.

The negative results of Buff are understood when the current density he employed is calculated. Under no conditions have the authors been able to get deposition of the metal at a current density as low as he used; nor have they with any but very impure acids been able to duplicate the results. Like Buff, the other workers, Schick, Cowper-Coles and Ferée, have probably used too low current densities.

Some of the claims of Placet and Bonnet (U. S. Patent 526, 114, Sept. 18, 1894) are sound. It is very probable that solutions of commercial chromic acid and of chromates, to which have been added various substances which aid in the reduction, may not be used in a continuous and economical process for the extraction of chromium, since the efficiency is so rapidly decreased by the formation of the reduction products. By oxidizing these, however, it would be possible to continue the extraction of the metal, making the process continuous. There is nothing to prevent the use of this method in the laboratory for the purpose of making pure chromium.

By selection of the proper impurity (*e. g.*, sulphuric acid), the authors have been able in a continued electrolysis to recover in the metallic form more than half the total chromium present in the solution. Had the reduced products been oxidized, this yield could have been carried to any limits desired.

The criticisms of Le Blanc on the work of Geuther, Placet and Bonnet and Street need radical change. The only justification for such criticism was due to the experimental conditions not having been described in sufficient detail by the various workers.

Electrolytic chromium may occlude as much as 250 times its volume of hydrogen. This may account for its hardness, which may make chromium coatings commercially useful for various purposes. Chromium would constitute in many cases a useful because more resisting, coating on metals which are more easily attacked.

It is possible to reduce chromic acid to the trivalent chromic salts in the presence of an excess of a mineral acid.

The authors regard chromium merely as the type of a large number of elements which, according to the degree of oxidation, are either acid or basic in their properties. The methods which they have used should, they think, be capable of application to numerous other cases, such as the rare earth elements.

Dr. Carveth showed various samples. The paper was discussed by Drs. W. R. Whitney and J. W. Richards. The latter said that on account of the possibility of existing in so many states the deposition of chromium is difficult. He asked what was the voltage of decomposition. This might give us a possibility of calculating approximately some data which are badly needed for the thermochemistry of chromium salts.

Electrolytic Precipitation of Silver.

A paper on this subject, by Mr. Ralph C. Snowden, read, in the absence of the author, by Dr. Carveth, reports on a continuation of the researches carried out at Cornell University, in order to test Professor W. D. Bancroft's hypothesis that the precipitation of metals from aqueous solutions, particularly for plating purposes, is as easily controlled and as purely chemical as any chemical process, "the electric current being simply a means to an end and having the nature of any of our power factors." One conclusion from this hypothesis is that since in general chemical practice substances which are precipitated from solutions separate out larger crystals if precipitated slowly, thus, in electrolytic deposition the size of the crystals of the metal decreases with the increase in current density at the cathode unless secondary or extraordinary reactions take place. Rotating the cathode, or stirring vigorously by other means tends to flatten out the crystals, probably by simple skin friction, and it is possible to obtain a bright, polished deposit in many cases by running up the speed of the cathode and using a correspondingly high-current density.

The object of the investigation of the author was to study the effect of current density and speed of rotation of the cathode upon the electro-deposition of silver, and to ascertain the possibility of obtaining a plating deposit of silver from the nitrate solution. The main results are as follows:

A very finely crystalline deposit of silver can be obtained from a silver nitrate solution by rotating the cathode rapidly and keeping the anode and cathode solutions separated. The size of the crystals decreases with the increase in current density and the increase in the rate of stirring at the cathode.

The addition of small amounts of organic "colloids" to the solution makes the deposit very amorphous, and causes the precipitated metal to assume a colloidal state.

The presence of free nitrate acid decreases the size of crystals but slightly.

The paper was discussed by Messrs. Carhart, Sadtler, T. W. Richards and Kern, the latter showing a silver deposit obtained by the process of A. G. Betts, described in this journal, p. 145 of our last issue. Some remarks were also made with respect to the silver coulometer—a term which was very strongly recommended instead of voltameter, since this instrument measures coulombs.

Electrodeposition of Metals on Aluminium.

A paper presented by Mr. Alexander Lodyguine described some results of experiments with the electro-deposition of metals on aluminium. The object was to cover very thin aluminium plates with layers of antimonious lead or with antimony for use in light storage batteries; these coatings to be as thin as compatible with the complete protection of the aluminium from the action of the electrolyte. The author thinks that the principal cause for the failure in depositing metals on aluminium lies in the difficulty to keep the aluminium surface free from any compounds of aluminium in contact with it, and that not even the most vigorous scrubbing, brushing and washing, in alkalies, acids and water, suffices for arriving at these results. Any electrolyte that attacks the aluminium must be discarded, however slight and slow the attack may be.

The author did not find a good solution from which he could deposit lead or antimonious lead directly on an aluminium plate. He therefore covers the aluminium plate first with a coating of copper. He uses an anode of pure copper and an electrolyte of pure water, with a few drops of sulphuric acid

in it; voltage 0.5, current density 0.0013 ampere per square inch. The plate is taken out after half an hour and vigorously washed and brushed in water, in a solution of hydrochloric acid, in a solution of caustic soda and once more in water, after which it is put again into the electrolyte. The same operation is repeated several times, until the plate is evenly and entirely coated with a fine and adherent coat of copper. After that the plate can be treated as an ordinary copper plate. (It may, for instance, be tinned for many practical uses.)

To deposit antimony on the copper-plated aluminium plate, the author uses a concentrated solution of protosulphide of sodium, Na_2S, with an excess of the protosulphide in the vat. Lumps of trisulphide of antimony, SbS, are placed in a porous cell of very oblong form, around a carbon plate; the cell is filled with the electrolyte and placed in a glass jar filled with the same electrolyte. Two plates of aluminium, coated with copper, are used as cathodes. The antimony adheres firmly to the plate, is of very fine structure and can be polished. The deposit can be continued as long as the monosulphide of sodium is not transformed into polysulphides. Voltage of deposition 1 to 1.5, current density 0.0013 amperes per square inch. The amount of antimony deposited per ampere-hour was found to be 0.833 grams (the theoretical value being 1.49).

Reduction of Titaniferous Ores.

A second paper by Mr. Alexander Lodyguine gave the results of experiments with the reduction of titaniferous ores. While the magnetites, hematites, etc., now available for the large iron and steel plants will, according to the author, sooner or later be things of the past, this country has inexhaustible deposits of titaniferous ores. Table I is a list of the United States Geological Survey of the more prominent localities in the United States where titaniferous ores are found, with the brief analyses of a number of representative ones:

Table I.

	Iron Oxides.	Titanic Oxides.
Iron Mountain, Col.	62.00	10.00
Iron Mountain, Col.	70.50	14.00
Mayhew Lake, Minn.	80.78	12.09
Church Mine, Hunterdon Co., N. J.	69.40	10.52
Naughtright Mine, Morris Co., N. J.	89.39	7.50
Split Rock Mine, Essex Co., N. Y.	61.83	14.70
Iron Mountain, Essex Co., N. Y.	55.82	16.37
Tunnel Hill, Essex Co., N. Y.	49.17	16.45
Little Pond, Essex Co., N. Y.	53.15	5.21
Lake Sandford, Essex Co., N. Y.	87.20	10.73
Lake Sandford, Essex Co., N. Y.	55.64	15.77
Rockingham Co., N. C.	66.56	13.71
Rockingham Co., N. C.	79.78	12.08
Cumberland Hill, R. I.	40.00	15.30
Cumberland Hill, R. I.	45.62	9.93
Cumberland Hill, R. I.	58.50	3.66
Near Laramie, Wyo.	61.99	23.49
Near Laramie, Wyo.	73.52	23.18
Near Laramie, Wyo.	73.01	22.43

The most important deposits of titaniferous magnetite, so far as size and accessibility are concerned, occur in the Adirondack Mountains, near Westport, Elizabethtown, and Lake Sandford, in Essex County, N Y.

And yet the ironmasters of to-day will not allow over 1 per cent of titanium in the ores they use, and many will not touch a titaniferous ore with tongs. The difficulty is that these ores smelt hard in the now existing types of furnaces, besides choking the blast furnaces. New types of furnaces and new methods of smelting are needed for the purpose.

The author referred to the splendid pioneer work done by Mr. Auguste J. Rossi, and then gave a brief account of some experiments made by himself with a Canadian ore in an electric furnace of small capacity (2 kg.). No particulars of the process are given, but the author states that from 2,000 grammes of ore he obtained, as an average, about 840 grammes of metal. The amount of iron in 2,000 grammes of ore was 1,006 grammes, and the amount of titanium 197 grammes, so that the loss in iron is equal to 16.5 per cent, and in metal to 30 per cent. The analysis of three different samples of iron obtained from his furnace and by his methods from the same ore are as follows: Fe 95.57, 84.70, 80.34; Si 0.40, 0.40, 1.40; S no, 0.60, 0.20; P no, 0.08, 0.09; Ti traces, 13.79, 17.22; Al traces; C "some;" total of chemically pure metal 95.57, 98.49, 97.56. The method of treatment was, of course, different in the three cases.

The analysis of the slag left after smelting the first sample showed: Fe 22.46%, SiO_2 14.77%, Al_2O_3 14.55%, CoO 8.27%, TiO_2 17.07%. From this slag ferrotitanium, very rich in titanium, can profitably be extracted.

He then gives some notes on the amount of power used, and concludes that for the reduction of one short ton of steel, or of ferrotitanium in his furnace and by his method, about 1,570 kw-hours are needed. Some figures are given on estimated cost, in comparison with the blast furnaces and with the electric furnaces reported on by the Canadian Commission.

The author thinks that in the high value of the by-products lies the real advantage of titaniferous ores. The by-products that are obtainable from reduction of titaniferous ore into steel are many, and they are all valuable.

Ferro-titanium is one of them. When it contains a small amount of titanium it is excellent for the wheels of railroad cars. It stands tear and wear a great deal better than any other steel. When it contains more titanium it is so hard that it can be used for cutting glass, etc. Titanium carbide is another valuable by-product. It "is a great deal harder than carborundum, and cannot only stand its ground in competition with it, but can even conquer a large market from its rival." It can be used in very large quantities in the metallurgy of iron and steel. The mordants and pigments of titanium are of great value and can also have a large market. The silicide, the boride and the nitride of titanium are nearly as hard as diamond, and can polish and cut any precious stone, including the diamond.

These two papers of Mr. Lodyguine were discussed together. Concerning electroplating upon aluminium, Dr. J. W. Richards called attention to the commercial value of nickel-plated or chromium-plated aluminium ware to give its surface the resistance against corrosion, which is required for many purposes. He regretted that in the second paper no details are given on the methods by which one may vary the titanium in the final product. The gist is to keep the titanium exactly in check. Mr. A. J. Rossi replied that in his experiments he never encountered any difficulty; the treatment is quite similar to that of silica.

A paper, by Mr. Ernest Fahrig, on the treatment of low-grade ores and tailings by electrolysis was then read by title. Since no advance copies were printed the report on it must be deferred until the publication in the Transactions of the Society.

Specific Inductive Capacity of Oleic Acid and its Salts.

Dr. Louis Kahlenberg gives in this paper the results of a determination of the dielectric constant of free oleic acid and of a number of its typical salts. The dielectric constants of three samples of oleic acid at 20° C. were found to be 2.50, 2.57 and 2.60 respectively. Aluminium oleate has a dielectric constant of 2.40 at 20° C., ferric oleate 2.68, copper oleate 2.80, etc. A fine sample of cotton-seed oil had a dielectric constant of 2.30; eight samples of pure California olive oil 2.60, 2.55, 2.70, 2.45, 2.60, 2.60, 2.53, 2.70.

It thus appears that oleic acid has about the same dielectric constant as the oils which represent its esters with glycerine as the base. Moreover, the dielectric constant of oleic acid must be regarded as quite low if one considers that the

compound is unsaturated and that it contains the carboxyl group. With the exception of aluminium oleate, the metallic oleates measured have a slightly higher dielectric constant than free oleic acid, the results obtained apparently indicating an increase of dielectric constant with increase of the chemical equivalent of the metal used. It is of special interest that the specific inductive capacity of oleic acid is so slightly changed by the introduction of heavy metals into the compound. It would seem as though the characteristic electrical properties of the metals were almost entirely overcome by the union with the large, fatty radical of the oleic acid. It is further noteworthy that the oleates have nearly the same dielectric constant, whether in the solid or liquid state.

THE ROTATING DIAPHRAGM.

A paper on this subject was presented by Professor WILDER D. BANCROFT. In the absence of the author it was read by Dr. Carveth. If an acidified copper sulphate solution is electrolyzed between copper electrodes, and if a cylindrical graphite rod is interposed between the electrodes as a partial diaphragm, copper will be deposited on one side and oxygen developed on the other side of the graphite rod, if the impressed voltage is high enough. If we now reverse the position of the graphite diaphragm, by rotating it through 180°, the precipitated copper side will now face the cathode, and the copper will dissolve, while copper will precipitate on the graphite surface facing the copper anode. Until the copper on the surface facing the copper cathode has been completely removed, the polarizations at the two faces will balance each other and the diaphragm will be temporarily non-polarizable. The gist of Professor Bancroft's paper is that the same result may be obtained if instead of reversing the graphite diaphragm every so often, it is rotated rapidly. It will then behave like an ideally-reversible electrode. No visible amount of copper precipitates on such a rotating electrode, though a considerable proportion of the total current flows through the electrode. These facts were established with a graphite cylinder filling nearly the whole cross-section of the tank and revolving with a speed of 200 revolutions per minute.

Professor Bancroft considers the relation of the rotating diaphragm to the mercury diaphragm. In the Castner process there is a metallic diaphragm reversible with regard to sodium, and the sodium is carried from one mercury surface to the other, chiefly by a surface flow due to rocking. In the Rhodin cell the same result is obtained by centrifugal action. With a solid diaphragm there can be no diffusion and no surface flow, as the depolarization must be effected by rotation. The rotating diaphragm is therefore the analogue of the Rhodin mercury diaphragm, the difference between the two being the necessary result of one being solid and the other liquid.

Since polarization can thus be eliminated by rotation, Professor Bancroft asks whether this process is reversible and whether polarization can be made to cause rotation. Experiments made by him to detect a directional effect of a small difference of potential on a floating or suspended electrode showed, however, that this directional effect is small, and can easily be masked by surface tension phenomena and convection currents.

In the discussion Mr. Sperry pointed out that it would be interesting to determine experimentally the minimum speed for which the rotating diaphragm is reversible.

HEAT OF SOLUTION OF ALUMINIUM BROMIDE IN ETHYL BROMIDE.

A paper on this subject was presented by Dr. H. E. PATTEN, and was read, in the absence of the author, by Dr. J. W. Richards. The main results of the investigation of the author are as follows: The heat of solution of aluminium bromide in ethyl bromide was determined near 20° C. at six concentrations: 1.497 per cent, 23,097 calories; 2.23 per cent, 20,354 calories; 10.2 per cent, 17,750 calories; 25.5 per cent, 11,540 calories; 37.1 per cent, 7,357 calories; 41.8 per cent, 6,077 calories.

The voltage required to decompose a solution of aluminium bromide in ethyl bromide, liberating aluminium and bromine, may be roughly calculated from the thermal data of the heat of formation of anhydrous $AlBr_3$ plus its heat of solution in ethyl bromide for dilute solution. The difference between this calculated decomposition voltage and that experimentally obtained is 0.13 volt, or 23.5 per cent of the total voltage attributable to the heat of solution. But if we take the total voltage of aluminium against platinum in this solution, 2.235, instead of the decomposition voltage (2.30 volts), the agreement is better. The difference then is 0.065 volt, which is 10.8 per cent of 0.552 volt, the total voltage to be calculated from the heat of solution. The presence of a secondary action at the cathode explains this discrepancy. "These results may be taken as indicating that with proper conditions, agreement between decomposition voltage calculated from thermal data and that determined experimentally by electrolysis will be found, provided the same chemical reaction obtain in the thermal and in the electrolytic experiments."

"On the other hand, one may take the ground that the experimentally-obtained heat of solution (for 1.5 per cent solution) is 38 per cent less than that which was to be expected from the experimental determination of the decomposition point of this solution, and on this basis may maintain that thermal data do not lend themselves to the calculation of decomposition voltage."

The heat of solution when plotted as a function of dilution has much the same form as the heat of solution curve for sulphuric acid in water.

The above results show that the solution of aluminium bromide in ethyl bromide is subject to the same energy considerations as obtain in aqueous solution, although its molecular conductivity curve is radically abnormal. At the same time the molecular formula of aluminium bromide, 11 per cent in etyl bromide, was shown to be very nearly $AlBr_3$ by the freezing point method. And this concentration lies in the region of rapid deviation of molecular conductivity from the trend of curve required by the theory of electrolytic dissociation.

In the discussion Dr. Theo. W. Richards objected to Patten's statement that he has applied Helmholtz' fromula while he used apparently Thomson's rule, thus using the total energy instead of the free energy. A complete treatment of the case would involve far more experimental work.

ATOMIC WEIGHTS AND ELECTROCHEMICAL EQUIVALENTS.

A paper on the interdependence of the atomic weights and the electrochemical equivalents was presented by Professor ARVID REUTERDAHL. In the absence of the author it was read in abstract by Dr. J. W. Richards. The paper is of a highly theoretical nature.

The investigation is essentially based on the relation $r\,t = c$, where r is the number of ampere-hours per gram per unit of valence, t the atomic weight, c a constant value. This relation is represented by the author graphically by means of polar coördinates, r being taken as radius vector and t as the corresponding vectorial angle. This relation is then made use of by the author for calculations in molecular physics. The author assumes the atom as a spherical shell, capable of expanding and contracting with pressure; the volume of this spherical shell is, at all times, proportional to the mass of the atom. Some of the results desired by the author are: The calculation of the electric charge of a corpuscle, the figure for the mass of the negative gaseous ion being used for this calculation. The author concludes that the number of ions, whether gaseous or liquid, liberated by a given quntity of electricity, is a constant, independent of the kind and mass of the ion; also, the charge carried by a free ion, whether gaseous

or liquid, is a constant quantity independent of the kind and mass of the ion.

"Gravitational and electrical mass may then be regarded as the two aspects in which mass manifests itself to us. On the one hand we have attractions, kinetic energy, absorption and integration; on the other hand we have repulsions, potential energy, self-conservation and differentiation; yet these are merely the two modes in which actual mass interactions take place. The conservation of mass and, therefore, the conservation of energy follows as a direct consequence from the previous considerations."

Electric Reduction of Different Oxides of Lead.

A paper by Mr. A. Lodyguine describes experiments which were undertaken to try to electrically extract lead from the lead peroxide of old storage batteries, instead of selling this peroxide to the junk dealers He used a mixture of the following composition:

Peroxide of lead, PbO^2	200	grs.
Chloride of sodium, NaCl	100	"
Sulphuric acid monohydr., H^2SO^4	131,5	" Solution of
Water, H^2O	168,5-2	" H^2SO^4 at 30% B.

A glass jar, with lead electrodes, was prepared to receive the mixture.

In Fig. 5, *a* is the negative electrode; *b* is the positive electrode; *c* and *d* are the insulated conductors connecting the electrodes with the battery giving the current; *e* is the above-mentioned mixture, and *f* is some of the liquid part of that mixture; *g* is a cover, with a pipe, *h*, by which the gas escapes.

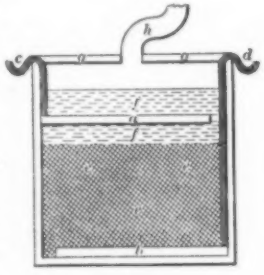


FIG. 5.—ARRANGEMENT OF EXPERIMENT.

When the mixture was introduced into the jar, the liquid part poured on, and the whole mixed with a glass stirrer, the chlorine gas began to escape by pipe *h*. The setting free of chlorine soon stopped, because hydrochloric acid could not continue to be replaced by sulphuric acid in the chloride of sodium without the application of heat or of electric current.

The instant that current passed through the mixture a violent setting free of chlorine occurred, and there appeared a formation of chloride of lead in the solid mixture. After a certain time, the length of which depended on the density of the current, a formation of some sulphate of lead was noticed. After another period of time some litharge was formed; finally, at a certain stage of the process, the mixture in the jar presented the appearance shown in Fig. 6. *a* is positive electrode; *b*-PbO^2; *c*-$PbCl^2$; *n*-$PbSO^4$; *d*-Litharge; *e*-Suboxide of lead, Pb^2O; *f*-spongeous lead; *g*-negative electrode; *h*-liquid part of mixture. The lower the current density the higher is the efficiency.

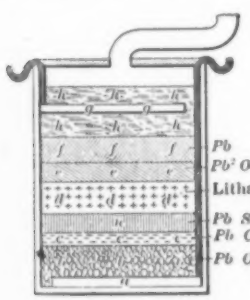


FIG. 6.—SUCCESSIVE STAGES OF REDUCTION OF PbO^2.

To the end of the experiment one could follow the increase and decrease of the different strata and their transformation into one another. At last only spongeous lead remained in the jar, all of the mixture having been transformed into it.

In these experiments the amount of lead deposited per watt hour was 2.1 grams, and per ampere hour 3 grams. The extraction of one short ton of pure lead from peroxide would, therefore, require about 435 kw.-hours, costing 87 cents, at a rate of $15 per kw.-year.

Utilization of Blast-Furnace Gases in Connection with the Electric Smelting of Iron.

An interesting paper on this subject was then presented by Mr. Auguste J. Rossi. After some general remarks on the importance of this problem for electrometallurgy, and especially for the manufacture of special steels in the electric furnace, the author passes over to the main object of his paper, *i. e.*, to show that whatever improvements have been already realized, or can legitimately be expected in future blast-furnace practice, tending to reduce to a minimum the amount of fuel per ton of iron, yet the amount of gases and, consequently, the available surplus, is not necessarily reduced in direct proportion to the fuel consumed. With special reference to Mr. Gayley's celebrated dry-blast run, the author emphasizes that it would be a mistake to conclude a priori that a smaller amount of coke per ton of iron necessarily gives a smaller weight of gases.

On the basis of the figures given in Mr. Gayley's report, Mr. Rossi calculates a total of 11,284 pounds gases per ton of metal, with 1,706 pounds of coke; the same amount of gases is practically given by L. Bell for the Edgar Thomson furnace, with moist air, for a consumption of 1,881 pounds of coke. This calculation shows that the amount of coke is not necessarily a criterion of the amount of gases, though it certainly enters into the calculation as an element, but that the composition of the ore smelted has a great deal of influence.

According to the latter, more or less limestone will be required giving out CO_2 in the gases, and we cannot conceive a blast furnace smelting chemically pure oxide of iron. If the ore is richer and the percentage of gangue is low, it will contain more oxide of iron, more oxygen, and will require more carbon for the reduction. As the heat necessary to reduce 1 kg. of iron from its oxides, to impregnate it with carbon, silicon and phosphorus, and to melt the product represents *several* times the number of calories required for the gangue of the ores and charges to be transformed in slag and melted and for its volatile matters to be gasified, for these reasons, with such *richest ores* as we can practically assume would be smelted, it is not likely that this amount of gases could fall to less than some 8,000 pounds to 9,000 pounds per ton of iron, even were the consumption of coke to fall as low as 1,500 pounds or below.

The figure of 9,000,000 thermal units per ton, assumed by some writers as *the total heat of the gases* for a consumption of 1,700 pounds of coke, would correspond at a heat value of these gases at 1,280 thermal units per pound to only 7,000 pounds of gases per ton of iron, a figure difficult to establish in the ordinary condition of ores; at any rate, for Mr. Gayley's remarkable run, even with an amount of coke of only 1,706 pounds per ton, as calculated from his charges, we have still over 11,000 pounds of gases. But let this figure of 9,000,000 thermal units, as total heat of the gases per ton of iron, stand as it is, and let us utilize as available, as the same writer says, only 52 per cent of it, or 468,000 thermal units. At 10,000 thermal units per effective horse-power-hour in gas engines we come to his figure, 468-horse-power-hour, as available surplus per ton, or, for 2,240-ton hour, to over 1,000,000-horse-power-hours surplus. The author considers himself justified, in conclusion, to assume that this figure is the minimum possible in the best provisions of the blast-furnace practice of the future as to consumption of coke per ton of iron and best condition of ores and steel. It is one which, if only but partly utilized, opens new and great possibilities for electric smelting.

This paper elicited a very lively discussion. Mr. E. R. Taylor agreed with the author of the paper that here is a source of power available for profitable development. Mr. H. S. Blackmore mentioned another example of the utilization of

what heretofore had been wasted. On the other hand, the gas-engine proposition in the whole was strongly attacked by Mr. Herbert H. Dow (Dow Chemical Co., Midland, Mich.), who emphasized its complication and the high investment involved. He is entirely in favor of steam engines. He thinks the term "waste gases" of blast furnaces is a misnomer, since they are used under boilers, etc. Mr. E. A. Sperry seconded him, and also emphasized that capital is expensive in this country, and that the interest factor and the high labor charge speak against gas power; coal and water power are cheaper. Dr. Joseph W. Richards, in a detailed reply to these statements, agreed that the commercial conditions are different in Europe and in the United States, and this fact accounts for the slow development of the utilization of blast-furnace gases in this country. Nevertheless, the development is going on, since the method has its undeniable commercial advantages. It is true, we have now cheap fuel, but we must be economical. Not so long as fifty years ago one could see blast furnaces, with open top, lighting at night time the country in the neighborhood; hence the name, waste gases, and this name has remained, although these gases are now used under boilers, etc. Dr. Richards stated that the Pittsburg plants will be equipped with the new system within three or four years. Plans and drawings have already been prepared for the most important plants of the United States Steel Corporation. The speaker then explained the importance of this development for electric-furnace steel, and predicted that for making the finer qualities of steel the crucible process will be replaced by the electric furnace within the next five years.

THURSDAY SESSION.

This session was again held in Lowell Hall of the Massachusetts Institute of Technology. Most of the papers presented at this session were illustrated by experiments, lantern slides or exhibits. Mr. A. J. Rossi exhibited a very interesting and full selection of samples, which he has produced in the electric furnace, especially in connection with the problem of smelting titaniferous ores.

ELECTROSTATIC METHOD FOR SEPARATING AND CONCENTRATING ORES.

A paper by Professor LUCIEN IRA BLAKE described his and L. N. Moscher's electrostatic separation process. In the absence of the author the paper was read by Mr. C. E. Locke. The process depends on the difference in the electric conductivity of the constituents of a mechanical mixture of various materials, and on the fact that, according to the conductivity, the electrostatic charge required by different materials from the same source of electric charge in the same time is different. Thus, if the mixture consists of a finely-crushed non-conductor, and of a finely-crushed conductor, and is brought in contact with a charged surface, the latter will receive a charge, while the former remain uncharged. Now, electrostatic repulsion of the charged particles from the charged surface will result, while the uncharged particles are not repelled. In this way the charged particles are separated from the uncharged ones, and this fact is made use of in the electrostatic separator.

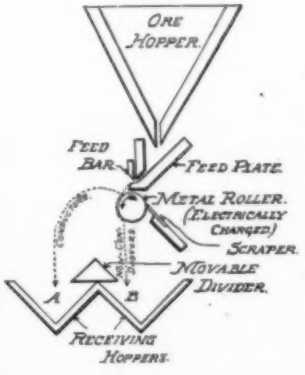


FIG. 7.—ELECTROSTATIC SEPARATOR.

The author first gave some mathematical formulas, which show that the process depends for a given separator with a given potential, on the electric resistance of the particles and on the electrostatic capacity of the particles in the position of contact. The resistance again is the sum of the internal resistance and surface resistance. The time in which a charge is acquired depends upon both the resistance and the capacity.

There is no possible way of predicting the action of the process on any given ore from a description or even from an analysis, but an actual trial must be made with a sample of ore. It is, however, possible to classify the minerals roughly, and the author gave the following list as a guide to their usual behavior:

Conductors.	Non-conductors.
Native metals.	Quartz.
Pyrite.	Calcite.
Chalcopyrite.	Limestone.
Galena.	Porphyries.
Graphite.	Slates.
Molybdenite.	Sandstones.
Copper glance.	Garnet.
Silver glance.	Spinel.
Gray copper.	Zinc blende.
Most sulphides.	Zinc carbonate.
Most copper minerals.	Barite (heavy spar).
Most iron minerals.	Gypsum.
Most silver minerals.	Granite.
Most manganese minerals.	Fluor-spar.
Tellurides.	Most silicates.
Black sands.	Most gangue rocks.

In a general way most sulphide minerals and most copper, iron, etc., minerals are conductors, while the gangue, waste minerals, quartz, etc., are non-conductors. Blende (zinc sulphide) is an exception to this general rule, being a non-conductor; and this is important for practical applications.

The process in practice requires, first, crushing; second, drying; third, suitable feeding to the charged surface; fourth, collection and removal of the separated products.

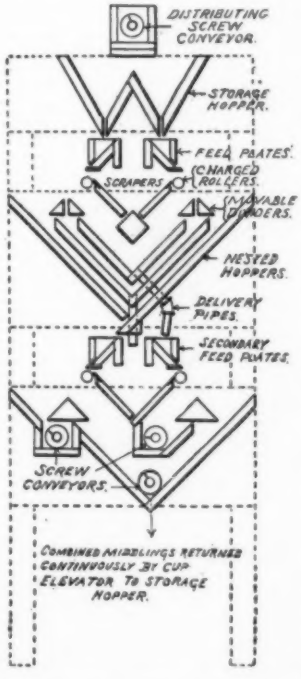


FIG. 8.—ELECTROSTATIC SEPARATOR.

Coarse crushing is preferable, but it must be fine enough to liberate the crystals, one from another. All materials to be delivered to the separator must be absolutely dry. This almost invariably means the use of heat, and the use of a direct-heat rotary dryer with boiler setting has been most satisfactory.

The construction of the separator itself is clearly shown diagrammatically in Figs. 7 and 8, while Fig. 9 gives the exterior view of an electrostatic separator. All these pictures are self-explanatory.

The standard type of separator, as built at present, has a nominal capacity of 12 tons in 24 hours. This varies, of course, within wide limits, depending upon the size of crushing, dust present, percentage of products, etc. The machine is chiefly built of wood in two similar sections, and is really two machines, standing side by side or connected in tandem, to fill a long, narrow space.

The size of the machine is 12 feet by 12 feet by 7 feet (with an elevator 5 feet higher, or 12 feet over all).

The voltage required is 350,000, and is furnished by a special induction machine. The leakage is considerable, but the total power expanded per machine is only 1 horse-power.

Most of the electrostatic separators now in practical use are used for separating pyrite or marcasite from zinc blende. This is done without roasting.

Not only does the process remove the iron minerals from zinc blende, but also lead, copper and other impurities. This

FIG. 9.—EXTERNAL VIEW OF ELECTROSTATIC ORE SEPARATOR.

means that when complex sulphide ores are concentrated on jigs or tables as a preliminary step to separating the middlings, it is not necessary to make a low-grade lead concentrate, carrying a high percentage of zinc and iron, in order to get a

TABLE II

Description	Products	% Zinc.	% Lead.	% Iron.	Remarks
Leadville, Col., Zinc middlings Wilfley tables	Orig.	30.48	3.21	21.60	20 mesh. (Combined iron 4.87%)*
	Iron.	9.04	8.00	35.11	
	Zinc.	51.20	0.62	6.40	
Joplin, Mo., Zinc middlings from jigs	Orig.	49.53	2.52	10.78	10 mesh. Lead practically all removed
	Iron.	2.92	9.92	37.44	
	Zinc.	62.31	trace	1.57	
Benton, Wis., Zinc middlings from jigs	Orig.	29.15	5.16	20.90	6 mesh. Iron sold to acid burners
	Iron.	5.07	8.40	38.88	
	Zinc.	58.40	0.23	2.16	
Silverton, Col., Zinc middlings Wilfley tables	Orig.	23.12	8.00	23.87	24 mesh.*
	Iron.	9.04	15.56	30.35	
	Zinc.	49.73	2.08	4.77	
Idaho lead and zinc, table Concentrates	Orig.	25.87	20.40	12.02	High silver*
	Lead.	4.45	50.58	16.14	
	Zinc.	45.11	3.81	7.40	
Nevada Chalcopyrite in garnet		Copper			12 mesh. Saving 81% of the copper. Crude ore; no dust removed
	Orig.	3.20	....	....	
	Conc.	12.94	....	....	
	Tlgs.	0.40	....	....	
Arizona copper Carbonate in limestone	Orig.	4.60	....	....	20 mesh. Saving 70% of the copper. Crude ore. Heated to redness.
	Conc.	33.89	....	....	
	Tlgs.	0.79	....	....	
Michigan Native copper in sandstone	Orig.	2.68	....	....	30 mesh. Saving 76% of the copper
	Conc.	38.70	....	....	
	Tlgs.	0.27	....	....	
Utah Chalcopyrite in heavy spar	Orig.	6.06	....	....	Saving 88% copper
	Conc.	26.81	....	....	
	Tlgs.	0.93	....	....	
New Mexico Gold bearing Pyrite in quartz			Iron	ozs. gold	Saving 74% of the gold
	Orig.	1.14	11.60	0.80	
	Conc.	4.20	36.12	2.42	
	Tlgs.	0.44	1.27	0.14	

Those lots marked * also contained considerable gold and silver values, which largely followed the lead and iron.

middling product free from lead. Lead can be freely sent over to the middling product if desired, since it will be removed, together with the iron and copper, by the separator.

Some of the results obtained in commercial practice on various kinds of ore are given in Table II.

The paper was briefly discussed by Messrs. J. W. Richards and C. P. Townsend.

Colloids.

A lecture on this subject, with a series of very interesting experiments, was held by Dr. W. R. Whitney. To bring an interesting and still little understood problem "before a new crowd" was the object of the lecturer, who pointed out that we have here to do really with an electrochemical problem, since we have here migration of material under the influence of an electric current, precipitation by electrolytes, etc. Dr. Whitney gave a general summary of what we know at present on colloids.

Colloids are apparently solutions or suspensions, but they are characterized by the feature that they do not exert a measurable osmotic pressure. Further, two classes of colloids may be distinguished: positive and negative colloids. A positive colloid precipitates a negative colloid and vice versa, but a positive colloid does not precipitate a positive colloid, and a negative colloid does not precipitate a negative colloid. Under the influence of an electric current the two classes of colloids migrate in opposite directions.

In most cases we have to do with particles in suspension, perceptible by the microscope. They are then seen to be in perpetual movement, like the picture we have formed of kinetic motion of molecules.

Colloids were shown to migrate under the influence of a current in one or the other direction. The lecturer described the precipitation of colloids by electrolytes, and gave a summary of various methods of preparing colloids. For instance, by volatilization of a metal under water; thus, with two platinum electrodes slightly touched under water, without fusing the terminals together, a colloidal solution of platinum in water is obtained. Further, production of a colloidal solution by putting a powdered substance into water. Another method is indicated by the reaction $Hg\,Cy_2 + H_2S = HgS + 2\,HCy$; in this method it is important that no electrolyte is present, as otherwise the colloid would be precipitated. All these explanations were illustrated by experiments.

The author then discussed the biological applications of colloids (blood, saps of trees) and the application for dyeing of textile fabrics; here it is important to produce the colloid inside the fabrics, then it cannot get out, since it does not exert an osmotic pressure and has no diffusing power.

The paper was discussed by Messrs. Franklin, Richards and Carveth.

An Electrolytic Switch.

A paper on this subject, with experiments, was presented by Mr. William Smith Horry.

The various properties of the aluminium cell are, besides its symmetric peculiarity, that it presents a high resistance to the passage of an electric current, it possesses capacity and it leaks. These qualities may be turned to account for the purpose of preventing those arcs that occur when a current, possessing inductance, is interrupted.

As all continuous currents possess more or less inductance, the voltage rises across the break when a switch carrying such a current is opened. This not only causes an inconvenient flash at the switch, but endangers the insulation of the circuit.

But if a suitable electrolytic cell be inserted across the break and the circuit then broken, there is no flash at the switch, and the increased voltage will force a current through the cell instead. The insulation of the cell then breaks down, but quickly re-establishes itself. After that the mains may be entirely disconnected without any spark.

To obtain the best results in this way an electrolyte for the cell should be chosen that substantially shuts off all current at the working voltage but that allows considerable leakage to occur with any increased pressure, a cell that has a critical

voltage a little above the line voltage. The most simple diagram of the circuits is that shown in Fig. 10. The circuit is represented as a line containing an electromagnet; there is a double-pole switch for the line, a rheostat contact and an aluminium cell. If the switch is closed no current will flow except that which leaks through the cell, but if the rheostat

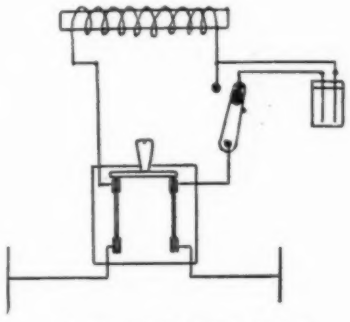


FIG. 10.—ELECTROLYTIC SWITCH.

arm is moved to the left then the full current will pass. To shut off the current the rheostat is returned to the position shown, then the switch is opened.

But the cell possesses capacity, and, if it be a large one intended to suppress a powerful arc, there will be a spark at the arm contacts when the terminals of the cell are connected. To make the circuit sparklessly the rheostat must be moved before the switch is closed. If the arm be moved first, both in opening and closing the circuit, there will be no spark at make, due to capacity, and no arcing at break, due to self-induction. This may be done with one movement of the switch handle, if there are provided three knives to it, the middle one having a more extended movement than the other two, so that it operates always in advance of the outer blades. Fig. 11 is a diagram of the circuits.

The construction of various cells of different sizes for different purposes was described. If such a cell be left unused its insulation slowly diminishes, but if used once a day that

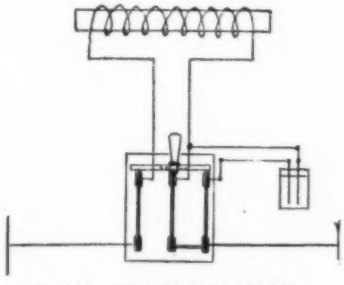


FIG. 11.—ELECTROLYTIC SWITCH.

tendency can hardly be noticed. On the other hand, the cell insulation increases with frequent use up to the critical point. For long-continued and rapid use a larger cell is necessary than for infrequent use, so that the heat generated by the continued arcing through the cell shall be radiated more rapidly.

The paper was briefly discussed by Messrs. Richards, Smith and Dow; the latter stated that he patented a similar device several years ago.

SILICON.

An interesting paper on this subject was presented by Mr. F. J. TONE. He began to describe the variety of products which may be obtained from a reaction between silica and carbon. To get a certain product alone it is all-important to provide a method of very closely regulating the temperature. He then described his own process for making silicon, which is operated at the works of the Carborundum Co., of Niagara Falls.

He mixes 60 parts of silica and 24 parts of carbon, according to the reaction:

$$SiO_2 + 2C = Si + 2CO.$$

The mixture must be made in very exact proportion. The furnace to be used must be specially designed in view of the fact that the temperatures of reduction and volatilization of silicon are very near together. For details of the construction of Mr. Tone's furnace the reader may be referred to the description and illustration on page 111 of our volume II.

The author then discussed the properties of silicon, samples of which were exhibited. The melting point is 1,430° C. In the neighborhood of the melting point it oxidizes in air, while at lower temperatures this is not the case. Silicon has a specific gravity of 2.34, and is between 6 and 7 in the scale of hardness.

Metallic silicon may become very important in the metallurgy of iron and steel, and is already very largely used in these industries in form of ferrosilicon and silicon-copper. Silicon may also be used to a certain extent as a substitute for aluminium in Goldschmidt's thermit reaction. Silicon is also suitable as a resistance material.

In the discussion Professor Elihu Thomson spoke of the great importance of the subject. It may find many uses. Silicon is an excellent resistance material when granulated and placed in a cylinder; by simply varying the pressure it is possible to change the resistance from 300 to 500 to 1. When the current density gets too high, however, the silicon particles are fused together. The resistance should, therefore, be artificially cooled. The specific resistance of silicon is two or three times that of carbon. Professor Thomson also spoke on casting silicon.

Mr. H. S. Potter stated that Mr. A. B. Albro has succeeded in developing a satisfactory process for substituting the cheaper silicon for the expensive aluminium in the thermit reaction of Goldschmidt. No further details were given in view of pending patents. Mr. Potter also mentioned that at high temperatures silicon is easily attacked by carbon dioxide.

MICROSTRUCTURE OF SILICON AND ALLOYS CONTAINING SILICON.

A paper on this subject was presented by Mr. A. B. ALBRO. The object was "not to propose or to defend any theories, but to show photographically recorded facts." Accordingly, the paper was a discussion of some 46 photomicrographs, which were shown by lantern slides, and which were extremely interesting. For this reason, however, it is impossible to abstract the paper satisfactorily without the photographs. We hope to be able to publish the paper in full with the photographs in a future issue. We will therefore simply state here that the author dealt successively with the microstructure of silicon, ferrosilicon, coppersilicon, showing in each case a marked characteristic influence of silicon, which can easily be detected microscopically. Two specially interesting statements were incidentally made; one to the effect that "a novel silicon process has been devised for Mr. George Westinghouse, by Mr. Henry Noel Potter," the process being not yet disclosed; the other statement referring to the observation made by Mr. Potter, that when silicon and silicon carbide are saturated with each other, the resulting material, called "carbosilicon," exhibits remarkable properties. Analysis proves this to contain the element and its carbide in proportions approximating very closely the formula $SiC + Si$ = (perhaps) Si_2C. The material is non-porous, harder than corundum, and so tough that a three-inch cube withstood heavy blows from a sledge on all its faces without fracture. Another interesting disclosure was the proof that fluid silicon, at temperatures near its melting point, does not dissolve carbon or react therewith to produce silicon carbide.

The paper was briefly discussed by Drs. Carveth and Richards.

The Mercury Arc.

In a paper on this subject, illustrated by numerous interesting experimental demonstrations, Dr. E. Weintraub gave a review of the work done by him in the Research Laboratory of the General Electric Co. As the author pointed out, the subject is of special interest to the electrochemist, "whose science can be in the main properly defined as the science of conductivity of a particular kind of matter, namely, of solutions and molten salts. The ionic theory of conductivity that had its birth in electrochemistry found afterwards fruitful applications in the theories of conductivity in gases. Any increase of our knowledge in this last named branch is in its turn apt to react on the general structure of that theory, and eventually influence the electrochemical ideas themselves."

The author first discussed the starting of an arc in metallic vapors. The distinctive feature of the conductivity of gases and metallic vapors, in contradistinction to that of metals and electrolytes, consists in that under ordinary conditions, in absence of exterior ionizing agents, the current itself has to create the material which is to carry it from one electrode to the other. As this material does not exist at the beginning, some special means must be used to start the discharge, and the author shows that the discharge must derive its carriers, at least in the immediate neighborhood of the cathode, from the material of that cathode. The application of a moderate electromotive force is of itself insufficient to start the process by which these carriers are formed out of the material of the cathode. The new fact discovered was that this formation of carriers (the "ionization" process) is started and the arc discharge made possible if a spark or a small arc is produced at the surface of the cathode. Several designs, based on this fact and using an auxiliary cathode for starting, were described. A consequence of the above fact is that Ohm's law does not hold in vapor arcs. The space separating the electrodes has an important influence on the velocity with which the starting takes place, but this influence is mainly of a negative character. The space must present as little hindrance as possible to the flow of ions starting from the cathode surface. Accordingly, the degree of vacuum must be the highest obtainable, and the more careful the exhaustion the more instantaneous is the starting.

In contradistinction to the cathode the anode plays no role whatever in the starting process. It receives the carriers of the current without any previous excitation.

The author then passed over to a discussion of the conditions of stability of the arc. Under ordinary circumstances there is a bright spot on the surface of the mercury cathode, which spot is continually wandering about on that surface. The wandering of this spot has not found as yet any very satisfactory explanation. The spot appears to be the place where the production of ions takes place, and the continuous motion of that spot means a disturbance of the ionization process and a danger to the existence of the arc. The wandering of the spot can be avoided in two different ways: either by making the surface of the cathode small, of the same magnitude as that of the spot, or by having a wire of iron or platinum project above the surface of the mercury. In this latter case the cathode spot is centered on the mercury surface right around the metallic wire.

The conductivity of the arc depends on the relative amounts of ionized and inert mercury vapor. If a sufficient condensing space is provided, so that the pressure of the ordinary mercury vapor volatilized from the cathode is kept down to a certain value, the conductivity of the arc is almost exactly proportional to the current. (The current creates its own ions.) The voltage across the arc is accordingly almost independent of the current.

In view of the fact that the ionization process at the cathode must be continuously maintained, the difficulties with an alternating current are evident, since with every change of polarity the ionization process at the cathode dies out, and moderate e. m. f's are not sufficient to start it again. If an alternating e. m. f. of moderate value is to maintain an arc in metallic vapors, one metallic electrode must permanently keep its negative sign, notwithstanding the perpetual change of polarity. Two arrangements for this purpose were described by the author.

In extending his researches to the arc discharge in vapors of alkali metals the author found that the regularities found for mercury vapors hold good for all other metallic vapors.

In the concluding part of his paper the author discussed the mechanism of the ionization process at the cathode. Disintegration is characteristic of the cathode of a metallic arc in an exhausted space. A transfer of matter either does not take place at all, or is so small as to be of the order of magnitude that would be required by the value of the electronic mass accepted in the modern theories. The cathode is the only space where the current-bearing material is formed. The temperature of the cathode is not the cause of ionization; it is probably in some way connected with the boiling point of its material, and is a result of the ionization process rather than the cause of it.

The author finally offers the following working hypothesis: He assumes that the mechanism of the conduction in the arc is similar to that in metals, and that an arc is, electrically considered, in the main a flow of negative electrons directed from the cathode toward the anode. While in the metal the number of electrons is a given quantity and the conductivity accordingly constant, the number of electrons crossing the surface of the cathode and entering into the arc must be proportional to the current. Accordingly, the conductivity of the arc is proportional to the current. The process of starting an arc serves to initiate the process by which the electrons are driven out from the metal into the space. The starting is probably produced by purely electrical causes. If this process, by means of which the negative electrons are projected out of the metallic mass, is started, it goes on of itself so long as a sufficient amount of energy is applied. The disintegration of the cathode is a mechanical accompaniment of this electrical process. The light emitted by the arc is not due directly to the radiation of the electrons. These negative electrons are probably the same in all arcs, and the light emitted changes according to the molecular material through which these electrons move.

Electric Arcs.

A lecture by Dr. W. R. Whitney on this subject, with experimental demonstrations, in which different arcs were projected on a screen, formed the able conclusion of this highly interesting session.

Dr. Whitney first referred to the unsuccessful attempts of applying something like Faraday's law to the arc. The arc starts at the cathode, and material is driven off from the cathode, but it does not go to the anode. He then showed various arcs; two solid carbon electrodes, plain carbon arc; electrodes, impregnated with salts (calcium fluoride and chloride); magnetite and carbon arc; iron and copper arc. The fact that it is the cathode which furnishes the carriers of the current was made evident by reversing the current between two unequal electrodes.

A vote of thanks was accorded to all who had shown courtesies to the Society and had contributed to the great success of the meeting. Then the meeting adjourned. The following three papers, which had been read by title, are abstracted from advance sheets:

A Low-Voltage Standard Cell.

A paper, by Dr. Geo. A. Hulett, deals with the following combination:

Cadmium, cadmium sulphate, cadmium amalgam, 5 to 13 per cent. It is based on the experimental fact that the electro-

motive force of cadmium amalgams, with concentrations within the above limits, has a constant value. Observations, began in May, 1904, by the author on this combination indicate that its electromotive force remains very constant, while cells set up at different times and with materials from different sources agree remarkably well, considering that one electrode is a metal in a solid state. The construction of the cell is described in detail and results of tests are given.

The e. m. f. of this cell is 0.05175 international volts at 20° C. The temperature coefficient is negative, = — 0.000244 volt per degree, "and practically linear." The temperature coefficient is higher than could be wished, but the cell in the construction of the author takes up its true value in a remarkably short time, when brought from one bath to another, generally in less than 15 minutes. In a bucket of water the cell follows any ordinary temperature change as readily as a mercury thermometer.

The small e. m. f. is an objection for a primary standard, but there is a very considerable amount of work done in which small e. m. f's are to be accurately measured—for instance, temperature measurements with a thermocouple.

The fact that the e. m. f. and temperature coefficient are not only independent of the concentration of the electrolyte but even of the presence or absence of the solid salt, make the cell particularly interesting. The cell is strictly reversible at both electrodes, but it does polarize and is only to be used in the Poggendorf compensation method. The internal resistance is very small.

Electrolytic Precipitation of Nickel on Nickel.

In a paper on this subject Mr. Ralph C. Snowden refers to the well-known difficulty experienced in technical electroplating with replating nickel-plated work. It is often claimed that it must be entirely freed from the previous deposit of nickel, or the subsequent nickel will not adhere. The reason is that the old nickel coating has become "passive" and is coated with a film of some oxide. It is not possible to remove this film by ordinary means, but this may be accomplished by making the passive metal the cathode in an acid solution and passing a fairly large current for a short time. This will cause a heavy evolution of nascent hydrogen, part of which will be taken up by the metal, and the oxide will be reduced. Quick washing and transferring to the plating bath gives an active metallic surface, on which an adherent deposit can then be successfully plated. This was found to be correct by experiment.

For the preliminary treatment of the nickel cathodes a 3-normal solution of hydrochloric acid was prepared, and a current density used of 8 amperes per square decimeter. The electrodes were both of nickel and were placed about 4.25 cm. apart. The run lasted 4 minutes. Hydrogen was evolved copiously at the cathode. As soon as sufficient treatment had been given the cathode it was washed in clean water and plunged into the regular plating solution, which was made up:

Nickel ammonium sulphate, 6 aq..... 80 g.
Water ..... 1 liter.

The other conditions: Area cathode, ¼ dm^2; current density, 2.0 amp./dm^2; voltage, 3.8 volts; temperature, 18°; time, ½ hour.

In case a rolled nickel anode is used, the solution must be kept neutral or only very slightly acid by means of ammonium hydroxide. Too great acidity causes the precipitation of a spongy deposit. In the experiment of the author the deposit came out perfectly smooth and so adherent that it could be burnished and scratch-brushed with impunity. The "active" state of nickel is very unstable.

Diffusion in Electrolytes.

A paper, by Mr. Carl Hambuechen, describes an optical method for observing diffusion in electrolytes. The author first corrects an erroneous conception sometimes held, that is, that in an electrolytic vat there is a gradual change of density from the anode to the cathode. As a matter of fact, whatever differences of density there may be at the immediate surface (or in the pores) of the electrodes, there is almost no variation in density on a horizontal line extending across the cell. In all active electrolytic cells there is a continual systematic movement of the electrolyte aside from that caused by gases which may be liberated.

For instance, if a solution of iron sulphate is electrolyzed between iron electrodes, the solution becomes more concentrated immediately at the surface of the anode, and this heavy solution sinks to the bottom of the cell. Simultaneously the solution at the surface of the cathode becomes more dilute and rises in a steady stream to the top. The whole solution then becomes stratified by horizontal layers of different concentration, laying above each other. They may be shown by the following optical method:

The cell is made of such size that it can be placed as a slide in a stereopticon lantern, and, upon focusing, a good image of the cell is thrown upon the screen. Even if the boundary lines between liquid layers of different concentration cannot be seen by the naked eye within the cell, they are clearly shown on the screen, on account of differences in the refraction of the light as it passes through the solution of non-uniform density.

By studying the stratification of an electrolyte produced in this manner a number of the difficulties encountered in the electro-deposition of metals can be explained. The rapid rising of the cathode solution explains the corrugated appearance which metallic deposits sometimes assume, and the non-uniformity in the density of the electrolyte explains the differences in the appearance of the deposits at different parts of the cathode.

By tracing out in a cell of this sort the paths taken by the solution, methods can be easily devised for altering such paths so as to meet practical requirements by means of suitable baffle plates or by an arrangement of electrodes.

In the following we give an alphabetical list of those members and guests who registered at the meeting, but may say that quite a number of those present did not register:

A. B. Albro, N. L. Amster, Henry S. Blackmore, Wm. Hand Browne, Jr., John S. Browning, Herbert Buckley, Henry S. Carhart, H. R. Carveth, Alan A. Claflin, T. J. Clexton, G. W. Coggeshall, Geneva B. Davidson, Gustavus Drobegg, Frank D. Easterbrooks, R. Fleming, W. S. Franklin, A. H. Gill, H. M. Goodwin, M. L. Griffin, Mrs. M. L. Griffin, H. E. Heath, Carl Hering, Wm. Smith Horry, E. J. Hutchinson, Alois von Isakovics, W. McA. Johnson, Yogoro Kato, A. E. Kennelly, Edward F. Kern, W. H. Kimball, Chas. A. Kraus, F. Austin Lidbury, A. Lodyguine, H. T. Matthew, A. C. Melcher, Henry Noel Potter, Jos. W. Richards, Mrs. Jos. W. Richards, E F. Roeber, Auguste J. Rossi, Philip B. Sadtler, S. S. Sadtler, F. E. Schmitt, Fred'k F. Schuetz, Edmund T. Smith, H. M. Smith, W. O. Snelling, C. C. Speiden, E. A. Sperry, H. P. Talbot, Edward R. Taylor, Mrs. Edward R. Taylor, M. DeK. Thompson, Jr., Elihu Thomson, F. J. Tone, Clinton Paul Townsend, Wm. H. Walker, Olive M. Wallace, Ray Hill White, S. E. Whiting, W. R. Whitney, H. W. Wiley, C. Irving Zimmerman.

Nickel Free from Carbon.—We have received from Mr. E. Stütz, general manager of the Goldschmidt Thermit Co., of New York City, the first regulus of pure nickel free from carbon, produced in this country, with the aluminothermic reaction from United States materials. This carbon-free nickel is mainly applied to convey to cast iron certain mechanical properties highly desirable in cast-iron vats used in various chemical industries, especially for the evaporation of caustic alkalies.

Electric Furnace Steel.—We have received from Mr. E. A. Colby and Dr. Leonard Waldo part of the first steel made in the electric induction furnace in the United States. Mr. Colby's original patents, taken out in 1890, for this type of furnace, were referred to on page 134 of our last issue under correspondence.

Metallurgical Calculations.—III.

By J. W. Richards, Ph.D.

Professor of Metallurgy in Lehigh University.

The Use of the Thermochemical Data.

Simple Combinations.

If the problem is the simple calculation of how much heat is evolved in the combination of a given weight of one element with another, the factors needed, the heat evolved per unit weight of substance combining, are obtained by a simple division from the thermochemical data given. Thus, suppose the question to be the total heat evolved in Problem 3, in the oxidation in a Bessemer converter of

100 kilos. of carbon to carbonic oxide.
200 kilos. of carbon to carbonous oxide.
50 kilos. of manganese to MnO.
150 kilos. of silicon to SiO^2.
500 kilos. of iron to FeO.

The solution would be

$$100 \times \frac{29{,}160}{12} = 100 \times 2430 = 243{,}000 \text{ Calories.}$$

$$200 \times \frac{97{,}200}{12} = 200 \times 8100 = 1{,}620{,}000 \text{ "}$$

$$50 \times \frac{90{,}900}{55} = 50 \times 1653 = 82{,}650 \text{ "}$$

$$150 \times \frac{180{,}000}{28} = 150 \times 6429 = 964{,}350 \text{ "}$$

$$500 \times \frac{65{,}700}{56} = 500 \times 1173 = 586{,}500 \text{ "}$$

Total. 3,496,500 "

Complex Combinations.

If the problem is a step more complex, that is, includes the combination of compounds with each other to form a more complex compound, the molecular weights are still our guide, together with the thermochemical data given. If, for instance, the question above solved is complicated by the further requirement, to add the heat evolved by the formation of the slag, that is, of the MnO and FeO with SiO^2 to form silicate, we may calculate the heat of union of FeO and MnO with SiO^2 as follows:

	(Mn, Si, O^3)	= 276,300 Calories.
But	(Mn, O)	= 90,900 "
and	(Si, O^2)	= 180,000 "
therefore	(MnO, SiO^2)	= 5,400 "

$$\text{or, per kilo. of MnO} = \frac{5{,}400}{71} = 76 \text{ Calories.}$$

Similarly

(Fe, Si, O^3)	= 256,300 Calories.
(Fe, O)	= 65,700 "
(Si, O^2)	= 180,000 "
(FeO, SiO^2)	= 10,600 "

$$\text{per kilo. of FeO} = \frac{10{,}600}{72} = 147 \text{ Calories.}$$

Therefore the additional heat of formation of the slag may be

Wt. MnO = 64.5 kilos. × 76 = 4,902 Calories.
Wt. FeO = 64.28 " × 147 = 94,492 "

Sum = 99,394 "

Similar principles of calculation apply to all the oxygen-containing salts. Thus, if from the heat of formation of any sulphate we subtract the heat of formation of SO^3, and also of the metallic oxide present, the residue is the heat of combination of the metallic oxide with SO^2,—the weights involved being always those represented by the formulæ. Thus, calling MO any metallic oxide, we may express the principle as follows:

$$(MO, SiO^2) = (M, Si, O^3) - (M, O) - (Si, O^2)$$
$$(MO, SO^3) = (M, S, O^3) - (M, O) - (S, O^3)$$
$$(MO, CO^2) = (M, C, O^3) - (M, O) - (C, O^2)$$
$$(3MO, P^2O^5) = (M^3, P^2, O^8) - 3(M, O) - (P^2, O^5)$$
etc. etc.

Example:—What is the heat required to calcine limestone?

$$(CaO, CO^2) = (Ca, C, O^3) - (Ca, O) - (C, O^2)$$
$$= 273{,}850 - 131{,}500 - 97{,}200$$
$$= 45{,}150 \text{ Calories.}$$

This is the heat required to split up $CaCO^3$ (100 parts) into CaO (56) and CO^2 (44); the heat required is therefore

45,150 ÷ 100 = 451.5 Calories per kilo. of $CaCO^3$ decomposed
45,150 ÷ 44 = 1026. " " " CO^2 driven off.
45,150 ÷ 56 = 806. " " " CaO remaining.

And either of these quantities may be used, according to convenience in working the problem.

Double Decompositions.

If the thermochemical problem involves the simultaneous decomposition of one or more substances and formation of one or more others, then the chemical equation should be written, and a thermochemical interpretation given of all the energy involved in the passage from starting compounds to products. Every chemical equation can be thus interpreted, if the heats of formation of all the compounds represented in it are known. We obtain the net energy of the reaction by assuming that all the substances used are resolved into their elements, and that all the products are formed from their elements; the first item is therefore to add together the heats of formation of all the substances used, starting with their elements, and by changing the algebraic sign of this sum we have the heat necessary to decompose the substances used into their elements; the second item is similarly found by adding together the heats of formation of all the substances formed; the difference between these two items is the net energy of the reaction. In making these summations, regard must, of course, be paid to the number of molecules of each substance concerned, as shown in the reaction; because the tabulated data are the heats of formation of one molecule only; and to the algebraic sign of the heats of formation.

Examples: (a) What heat is evolved when dry ferric oxide is reduced by aluminium, in the Goldschmidt "Thermite" process:

$$Fe^2O^3 + 2Al = Al^2O^3 + 2Fe$$
$$-195{,}600 \quad | \quad +392{,}600$$
$$+197{,}000 \text{ Calories.}$$

(b) Write the equation showing the reaction of metallic sodium on water in excess

$$2H^2O + 2Na = 2NaOH + \text{aq. (excess water)}$$
$$-2(69{,}000) \quad | \quad +2(112{,}500)$$
$$-138{,}000 \quad | \quad +225{,}000$$
$$+87{,}000 \text{ Calories.}$$

(c) What heat is evolved in the reaction of water on calcium carbide to form acetylene gas?

$$CaC^2 + 2H^2O = CaO^2H^2 + C^2H^2$$
$$-(-6250) - 138{,}000 \quad | \quad +215{,}600 + (-54{,}750)$$
$$-131{,}750 \quad | \quad +160{,}850$$
$$+29{,}100$$

The last case leaves out the very small heat of solution of the calcium hydrate which would normally go into solution. If such a large excess of water was used that all the calcium hydrate formed could dissolve, the heat of formation of the hydrate in dilute solution, 219,500 Calories, would be used, and the final result would be 33,000 Calories. The case is also very instructive, because it contains two compounds which are endothermic, that is, their heat of formation is negative, and therefore, as in the case of CaC^2, heat is given out when it decomposes, while in the case of C^2H^2 heat is absorbed when it is formed.

(d) What are the heats of combustion of the gaseous hydrocarbons which form constituents of common fuels, expressed per cubic meter of gas burning, and with the water formed assumed remaining as vapor, uncondensed? To calculate these we write the equations of combustion, with water as gas, and find the sum total of heat evolved; since every molecule of gas burning represents 22.22 m^3 of gas, we can, by a simple division, obtain the value sought.

Methane:

$$CH^4 + 2O^2 = CO^2 + 2H^2O$$
$$-22{,}250 \quad | \quad +97{,}200 + 2(58{,}060)$$
$$+191{,}070 \text{ Calories.} \qquad = 8{,}598 \text{ per } m^3 \ CH^4.$$

Ethane:

$$2C^2H^6 + 7O^2 = 4CO^2 + 6H^2O$$
$$-2(26{,}650) \quad | \quad +4(97{,}200) + 6(58{,}060)$$
$$+683{,}860 \text{ Calories.} \qquad = 15{,}387 \text{ per } m^3 \ C^2H^6.$$

Propane:

$$C^3H^8 + 5O^2 = 3CO^2 + 4H^2O$$
$$-33{,}850 \quad | \quad +3(97{,}200) + 4(58{,}060)$$
$$+489{,}990 \text{ Calories.} \qquad = 22{,}050 \text{ per } m^3 \ C^3H^8.$$

By applying these principles to all the hydrocarbons whose heat of formation has been given in the tables, we obtain the following useful table, water being considered as uncondensed and cold:

Hydrocarbon.	*Molecular Heat of Combustion.* Calories.	1 m^3 (Calories)	1 ft^3 (B.T.U.)
Methane (gas)	191,070	8,598	966
Ethane (gas)	341,930	15,387	1728
Propane (gas)	489,900	22,050	2477
Ethylene (gas)	321,770	14,480	1627
Propylene (gas)	471,830	21,232	2385
Toluene (liquid)	906,990	.....	....
Benzene (liquid)	758,130	.....	....
Benzene (gas)	765,330	34,440	3869
Turpentine (liquid)	1,428,930	.....	....
Turpentine (gas)	1,438,330	64,725	7271
Naphthaline (solid)	1,223,690	.....	....
Naphthaline (liquid)	1,228,290	55,273	6209
Anthracine (solid)	1,690,150	.....	....
Acetylene (gas)	365,270	16,437	1846
Methyl alcohol (liquid)	148,270	.....	....
Methyl alcohol (gas)	156,670	7,050	799
Ethyl alcohol (liquid)	295,330	.....	....
Ethyl alcohol (gas)	305,430	13,744	1544
Acetone (liquid)	396,130	.....	....
Acetone (gas)	403,630	18,163	2040
(To the above we will add data for three other common gaseous fuels).			
Carbonous oxide (gas)	68,040	3,062	344
Hydrogen (gas)	58,060	2,613	293.5
Hydrogen sulphide	122,520	5,513	619

CALORIFIC POWER OF FUELS.

By using the principles explained we can calculate the calorific power of any combustible, with the aid of one or two simple assumptions. Regarding the water formed, we will consider in all ordinary metallurgical calculations that it remains uncondensed, thus putting it on the same footing as the other products of combustion. This amounts virtually to assuming that the latent heat of condensation of the vapor formed has not been generated in the furnace, an assumption which is quite justified if, as is almost always the case, the water formed inevitably escapes as vapor. If, in any special case, the products of combustion are in reality cooled down so far that the water does condense, then it would be proper to assume the higher calorific powers for the combustion of the hydrogen-containing materials, and thus a more accurate heat-balance of the furnace operation could be constructed. An instance of the latter might be the case of the partial combustion of a fuel in a gas producer, where the fuel gas is afterwards cooled before using, in order to condense from it ammonia water, etc. (Mond's producer). In this case, it is possible that some water formed by the partial combustion would be afterwards condensed, and to obtain a correct heat balance-sheet of the producer it would be necessary to assume that this heat had also been generated. Such cases occur very rarely in metallurgical practice, and it is therefore recommended to always use the lower calorific values, assuming water vapor uncondensed and its latent heat of condensation not to have been generated—unless the conditions of the problem point plainly to the opposite course as correct. It is no more correct to charge against a furnace the latent heat of condensation of the water vapor formed, than it would be to charge against it the latent heat of condensation of the carbonic oxide formed, if the conditions of practice are such that it is impossible to utilize in any useful manner either one of them. Those who persist in assuming that the latent heat of vaporization of the water formed by combustion is generated in and chargeable against the furnace, and then, of necessity, charge the same quantity against the heat carried off in the products of combustion, are in the great majority of cases adding to both sides of the balance sheet a quantity which cannot possibly be utilized, and are therefore distorting all the factors of heat generation and distribution. By thus abnormally increasing the sensible heat in the waste gases, they abnormally *decrease* the proportionate value of other items of heat distribution and utilization. I have dwelt on this matter at length, because it is of importance in furnaces using fuel, such as gas, rich in hydrogen; where, in some cases, the counting of the latent heat of condensation of the water vapor formed, in the escaping gases, would perhaps *double* the apparent chimney loss, and give distorted values to the whole heat balance sheet. What we are after, in every case, are the real facts and figures as to the working of a furnace or operation, and we must therefore judge the operation by a theoretically perfect standard, it is true, but not by a theoretically impossible standard; *i. e.*, our standard must be the theoretically possible one under the practical conditions necessarily prevailing. A radical reform is very much needed in just this respect,—in the treatment of the latent heat of vaporization of the water formed, by writers on metallurgical processes and problems of combustion.

Problem 4.

A natural gas from Kokomo, Ind., contained by analysis: CH^4 94.16, H^2 1.42, C^2H^4 0.30, CO^2 0.27, CO 0.55, O^2 0.32, N^2 2.80, H^2S 0.18 per cent.

Required:

(1) What is its metallurgical calorific power per cubic meter and per cubic foot?

(2) Comparing it with coal having a calorific power of 8000 Calories, how much gas gives the same generation of heat as a metric ton of coal?

(3) If the natural gas costs $0.15 per 1000 cubic feet, at what price per metric ton would the coal furnish heating power at the same cost for fuel.

Solution:—Requirement (1) Heat of combustion of 1 cubic meter:

CH^4	0.9416 ×	8,598 =	8095.9	Calories.
H^2	0.0142 ×	2,613 =	37.1	"
C^2H^4	0.0030 ×	14,480 =	43.4	"
CO	0.0055 ×	3,062 =	16.8	"
H^2S	0.0018 ×	5,513 =	9.9	"
		Total =	8203.1	"

In British thermal units per cubic foot we have

$$8{,}203.1 \times 3.967 \div 35.314 =$$
$$8{,}203.1 \times 0.11233 = 921.5 \text{ B. T. U. per ft}^3 \text{ (1)}$$

Requirement (2):

$$\frac{8000 \times 1000}{8{,}203.1} = 975 \text{ m}^3$$
$$= 34{,}450 \text{ ft}^3.$$

If the ton of coal be taken as 2240 pounds, instead of the metric ton of 2204 pounds, the equivalent volume is

$$34{,}450 \times \frac{2240}{2204} = 35{,}013 \text{ ft}^3.$$

Requirement (3):

$$\frac{34.450}{1000} \times 0.15 = \$5.16\tfrac{3}{4} \text{ per metric ton.}$$

or, per ton of 2240 pounds,

$$\$5.16\tfrac{3}{4} \times \frac{2204}{2240} = \$5.08\tfrac{1}{2} \text{ per long ton.}$$

Dulong and Petit's Law.

When a solid or liquid carbonaceous fuel is to be burned, its calorific power may either be determined directly in a calorimeter (which is the best way, if carefully done), or may be calculated from its analysis. In case it is determined calorimetrically, the weight of water produced per unit of fuel should be determined either in the same or by a separate experiment, and the latent heat of vaporization of this water subtracted from the calorimetric value of the fuel, in order to get its metallurgical, or practical, calorific power.

Example.—A coal gave 9215 calories per gram in the calorimeter, and its products of combustion gave up 0.45 grams of condensed water. What is its practical calorific power?

Taking the products cold, the heat of condensation per gram of water vapor may be taken as 606.5 calories (Regnault), and we therefore have obtained in the calorimeter

$$0.45 \times 606.5 = 273 \text{ Calories}$$

more than if the products were cold and water uncondensed. The practical calorific power is therefore

$$9215 - 273 = 8942 \text{ Calories per kilogram.}$$

Dulong and Petit's law, or method of calculation, is the statement that the calorific power of a fuel can be calculated from the amount of carbon, hydrogen and oxygen it contains by assuming all the carbon free to burn, the oxygen to be all combined with hydrogen in the proportions of O^2 to $2H^2$ (32 to 4), and that the rest of the hydrogen is free to burn.

Example.—Taking the bituminous coal of Problem 1, containing carbon 73.60, hydrogen 5.30, nitrogen 1.70, sulphur 0.75, oxygen 10.00, moisture 0.60, ash 8.05, its calculated calorific power is per kilogram:

Carbon	0.7360 ×	8100 =	5962	Calories.
Hydrogen	0.0530			
	0.0125			
	0.0405 ×	34,500 =	1397	" (water liquid).
Sulphur	0.0075 ×	2196 =	17	"
		Total	7376	"

This calculation is made, however, on the assumption that all the water in the products is condensed to liquid, *i. e.*, not only the water formed by combustion of the free hydrogen, but also the already-formed H^2O containing the oxygen of the coal, as well as the moisture present to start with. To obtain the practical calorific power by calculation we must subtract from the above-generated heat the latent heat of *all* the vapor of water in the products, as follows:

Moisture in coal	0.0060 kilos.
Moisture formed by combined hydrogen	0.1125 "
Moisture formed by free hydrogen	0.3645 "
Total	0.4830 "

Latent heat of evaporation = 606.5 × 0.4830 = 293 Calories.
Practical calorific power, water all as vapor = 7083 Calories.
The values thus calculated are found to agree satisfactorily with the laboratory and the practical calorific powers of the fuels.

The Theoretical Temperature of Combustion.

If we start with a cold fuel and cold air the maximum temperature which can be obtained by the combustion is simply that temperature to which the heat generated can raise the products of combustion, assuming that all that heat resides primarily in the products as sensible heat. This is then a problem in physics, in which we have a known amount of heat available, and the question is to what temperature it will raise the products of combustion. The problem is at once soluble when we know the mean specific heats of the products of combustion and their respective quantities.

Until a few years ago these specific heats at high temperatures were unknown, and very false results were obtained by assuming constant specific heats from ordinary temperatures up, and values were thus calculated which were known to be hundreds, and in some cases thousands, of degrees too high. The most satisfactory values for the specific heats of the fixed gases and water vapor and carbonic oxide are those determined by Mallard and Le Chatelier, and their proper use has entirely solved the question of theoretical temperatures of combustion, and removed a positively disgraceful discrepancy between theory and practice. The specific heats of these gases increase with temperature, so that the actual specific heat of a cubic meter (measured at standard conditions) is, at the temperature t,—

for air N^2, O^2, H^2, CO $-S = 0.303 + 0.0000054t$
" " CO^2 $-S = 0.37 + 0.00054t$
" " (vapor) H^2O $-S = 0.34 + 0.00030t$

For calculating the quantity of heat needed to raise the gas from O° to t°, however, we need the mean specific heats, Sm, between O° and t°. These are, of course, the above constants plus half the increase, viz.:

for N^2, O^2, H^2, CO $- Sm = 0.303 + 0.000027t$
" CO^2 $- Sm = 0.37 + 0.00027t$
" (vapor) H^2O $- Sm = 0.34 + 0.00015t$

and the quantity of heat needed to raise 1 cubic meter (at standard conditions) from O° to t° is

for N^2, O^2, H^2, CO $- Q\ (o\text{-}t) = 0.303t + 0.000027t^2$
" CO^2 $- Q\ (o\text{-}t) = 0.37t + 0.00027t^2$
" H^2O $- Q\ (o\text{-}t) = 0.34t + 0.00015t^2$

or, finally, the quantity of heat needed to raise 1 cubic meter (measured at standard conditions) from t to t' is

for N^2, O^2, H^2, CO $- Q\ (t'\text{-}t) = 0.303\ (t'\text{-}t) + 0.000027\ (t'^2\text{-}t^2)$
" CO^2 $- Q\ (t'\text{-}t) = 0.37\ (t'\text{-}t) + 0.00027\ (t'^2\text{-}t^2)$
" H^2O $- Q\ (t'\text{-}t) = 0.34\ (t'\text{-}t) + 0.00015\ (t'^2\text{-}t^2)$

And the mean specific heat, Sm, between any two temperatures is

for N^2, O^2, H^2, CO $- Sm\ (t'\text{-}t) = 0.303 + 0.000027\ (t' + t)$
" CO^2 $- Sm\ (t'\text{-}t) = 0.37 + 0.00027\ (t' + t)$
" H^2O $- Sm\ (t'\text{-}t) = 0.34 + 0.00015\ (t' + t)$

Examples:

(1) What is the temperature of the hottest part of the oxy-hydrogen blowpipe flame?

According to the equation $2H^2 + O^2 = 2H^2O$, the hydrogen gas forms an equal volume of water vapor. (Equal numbers of molecules.) The heat of combustion of one cubic meter of hydrogen is 2613 Calories. The question is, therefore: "To what temperature will 2613 Calories raise one cubic meter of water vapor?" The answer is, using the data above,

$$Q\ (0\text{-}t) = 0.34t + 0.00015t^2 = 2613$$

Whence $t = 3191°$

(2) What is the maximum temperature of the hydrogen flame burning in dry air?

The heat evolved is, as before, 2613 Calories, and there is formed also one cubic meter of water vapor, but the products will contain also the nitrogen which accompanied the 0.5 cubic meter of oxygen necessary for combustion, viz.: $\frac{0.5}{0.208} - 0.5 = 1.9$ cubic meters, and this is heated as well as the water vapor. Therefore,

$$Q\ (0\text{-}t) = (0.34t + 0.00015t^2) + 1.9(0.303t + 0.000027t^2) = 2613$$

Whence $0.916t + 0.0002013t^2 = 2613$

And $t = 2010°$

(3) What is the temperature of the air-hydrogen blowpipe, if 25 per cent excess of air is used above that required?

All the data are the same as above, except that to the products will be added $0.25\ (0.5 + 1.9) = 0.6$ cubic meters of unused air, which has the same specific heat as nitrogen, and therefore the equation becomes

$$Q\ (0\text{-}t) = (0.34t + 0.00015t^2) + 2.5\ (0.303t + 0.000027t^2) = 2613$$

Whence $t = 1764°$

This calculation brings out very clearly the uselessness and ineffectiveness of using more air than is theoretically necessary; any excess simply passes unused into the products of combustion, and thus reduces their maximum possible temperature. The obtaining of the maximum possible temperature depends upon accurately proportioning the supply of oxygen or air to the quantity of gas burned; an excess or a deficiency will result in a lower temperature.

COMBUSTION WITH HEATED FUEL OR AIR.

If the fuel itself or the air which burns it is preheated, the sensible heat in either one or in both is simply added to the heat generated by the combustion, to give the total amount of heat which must be present as sensible heat in the products of combustion. The effect is exactly the same as if the heat developed by combustion had been increased by the sensible heat in the fuel or air used.

What is the calorific intensity (theoretical maximum temperature) obtained by burning carbonous oxide gas? (a) Cold, with cold air; (b) cold, with hot air at 700° C.; (c) hot, with hot air, both at 700° C.

(a) Take one cubic meter of carbonous oxide. Calorific power 3,062 Calories; product one cubic meter of carbonic oxide, and 1.904 cubic meters of nitrogen.

Let t be the temperature attained; then

Heat in the 1 m^3 carbonic oxide $= 0.37t + 0.00027t^2$

" " 1.904 m^3 nitrogen gas $= 0.577t + 0.0000514t^2$

" " products $= 3{,}062$ Cal's. $= 0.947t + 0.0003214t^2$

Whence $t = 1947°$

(b) If the 2.404 cubic meters of air needed are preheated to 700° C., they will bring in as sensible heat

$$Q\ (0\text{-}700) = 2.404\ [0.303\ (700) + 0.000027\ (700)^2] = 552 \text{ Calories.}$$

The total heat in the products will be $3062 + 552 = 3614$ Calories, and therefore $0.947t + 0.0003214t^2 = 3614$

Whence $t = 2189°$

(c) If the gas itself is also preheated it brings in

$$Q\ (0\text{-}700) = 0.303\ (700) + 0.000027\ (700)^2 = 225 \text{ Calories.}$$

The total heat in the products will be $3614 + 225 = 3839$ Calories, and therefore $0.947t + 0.0003214t^2 = 3839$

Whence $t = 2284°$

Heating both gas and air to 700° before they burn thus raises the theoretical temperature from 1947 to 2284, or 337°.

Problem 5.

Statement.—The natural gas of Kokomo, Ind., contains by analysis: Methane (marsh gas) 94.16, ethylene (olefiant gas) 0.30, hydrogen 1.42, carbonous oxide 0.55, carbonic oxide 0.27, oxygen 0.32, nitrogen 2.80, hydrogen sulphide 0.18,—in percentages, by volume.

Required:

(1) The maximum flame temperature, if burned cold with the theoretical amount of cold, dry air necessary.

(2) The calorific intensity, if burned cold, with the requisite air preheated to 1000° C.

(3) The calorific intensity, if burned cold, with 25 per cent. more air than theoretically necessary, preheated to 1000°.

Solution:

[The practical calorific power of this gas has been already calculated in Problem 4 as 8203 Calories per cubic meter. The gas itself is always burned cold, because, if preheated, it decomposes and deposits carbon in the regenerators.]

The products of combustion of the gas, say per cubic meter, must first be found, using the formulæ for combustion.

Requirement (1):

	1 Cubic Meter of Gas.	Oxygen Needed. m^3	Products. CO^2	H^2O	SO^2	N^2
CH^4	0.9416	1.8832	0.9416	1.8832	.....	.....
C^2H^4	0.0030	0.0090	0.0060	0.0060	.....	.....
H^2	0.0142	0.0071	.....	0.0142	.....	.....
CO	0.0055	0.00275	0.0055	.....	.....	.....
CO^2	0.0027	.....	0.0027	.....	.....	.....
O^2	0.0032	0.0032	.....	.....	.....	.....
N^2	0.0280	.....	.....	.....	.....	0.0280
H^2S	0.0018	0.0027	.....	0.0018	0.0018	.....
		1.90155	0.9558	1.9052	0.0018	0.0280
Air required		9.14		(carrying in N^2)		= 7.238
						Total N^2 7.266

The heat generated will exist as sensible heat in the CO^2, H^2O, SO^2 and N^2 of the products. The mean specific heat of SO^2 per cubic meter is 0.444 at ordinary temperatures; what it is at high temperature has not been determined; we will give it the same index of increase as the analogous gas CO^2, and take for it $Sm\ (0\text{-}t) = 0.444 + 0.00027t$, or $Q\ (0\text{-}t) = 0.444t + 0.00027t^2$.

At the temperature attained by combustion, t, the products will contain the following amounts of heat:

$$N^2 = 7.266\ (0.303t + 0.000027t^2)$$
$$H^2O = 1.9052\ (0.34t + 0.00015t^2)$$
$$CO^2 = 0.9558\ (0.37t + 0.00027t^2)$$
$$SO^2 = 0.0018\ (0.444t + 0.00027t^2)$$

$$\text{Total} = 3.2044t + 0.00074057t^2 = 8203 \text{ Calories.}$$

From which $t = 1806°$ (1)

Requirement (2):

Heat in 1 m^3 of air at 1000° $= 0.303\ (1000) + 0.000027\ (1000)^2 = 330$ Calories.

" 9.14 m^3 " 1000° $= 3016$ "

Therefore: $3.2044t + 0.00074057t^2 = 8203 + 3016$

Whence $t = 2288°$

Requirement (3):

Excess air used $= 9.14 \times 0.25 = 2.285$ m³.

Heat in 11.425 m³ at 1000° $= 11.425 \times 330 = 3770$ Calories.

The heat capacity of the excess air must be added to the heat in the products at temperature t, viz.:

$$\text{Excess air} = 2.285\ (0.303t + 0.000027t^2)$$

making the total heat in the products (adding to previous expression.)

$$3.8968t + 0.00080227t^2 = 8203 + 3770$$

Whence $t = 2134°$

[The next instalment of these "Metallurgical Calculations" will discuss the heat necessary to produce reactions at high temperatures.]

Electric Smelting and Blast Furnace Gases.

By Auguste J. Rossi.

(Concluded from page 150.)

What has been said of blast furnace gases is equally true of the waste gases of the coke ovens which recuperate ammonia and tar products. They have been utilized in gas engines for generating power to operate the machinery or electricity for lighting purposes, and, in certain collieries in Germany, some 2500 hp. have thus been created last year.

The first experiments with these gases were made as early as 1895 in Scotland. The blast furnaces of this district using soft coal and being already provided with installations to collect the by-products, tar, ammonia, etc., the attention was naturally called to the value of these gases. Since then, and simultaneously in England, Belgium and Germany, papers have been published on this subject, and we give in a note at the end of this article references to the documents to be consulted. At Hoerde, in Germany, a 600-hp. machine was in operation as early as 1898. But in 1898, Mr. A. Greiner, general director of the Cockerill Iron Works, Seraing, Belgium, made an elaborate study of the question, both as to the heating capacity of these gases and their applications to gas engine study, which has appeared in a paper[3] read before the Iron and Steel Institute at their annual meeting, and, as the data he gives are based on numerous and authentical tests made under his direction, and continued for a period of some years, and that, furthermore, they are corroborated by other tests made in Europe since, and agree very well, as we will see, with figures furnished by Mr. Uehling; we will extract from this paper interesting data bearing on this question and compare them with those given by Mr. Thomson.

We will find that the discrepancies are not what they appear to be at first sight. Indeed, the amount of gases from a blast furnace varies necessarily with the amount of coke consumed per ton of iron, so that, for a consumption of 1700 pounds per ton of iron, instead of 2240 pounds, the two amounts may differ considerably, and if a comparison is to be made, it must be on the assumption of the same duty of coke and conditions of ore in both cases. The amount of gases used to heat the blast varies also necessarily according to the temperature at which the air is blown in the furnace, and, for instance, blast heated to 593° C. (Pittsburg district, 1890) will require *less* gases for the same volume than blast heated to 704° C. (Clarence Works, England). So, again, two figures which may appear wide apart may well be really agreeing very closely for the temperature of blast. As a consequence, that part of the gases which is supplied to the boilers, from the total amount generated in the blast furnace, may well be found to vary in these different conditions. Again, as to horse-power required per ton for blowing purposes, it will be so much the greater as the pressure of this blast, which may vary from 7 pounds to 10 pounds and much more, will be greater, and as this horse-power has to be subtracted, with the auxiliary power for hoists, etc., from the amount which the gases could supply in a gas engine, the *available surplus* may well differ, unless similar conditions are compared.

These blast furnace gases consist, in a general manner, of about 58 per cent to 65 per cent of nitrogen, with a balance of CO and CO_2, with a small quantity of hydrogen. The ratio of CO_2 to CO varies according to the furnace. Such a ratio as 0.70, as is obtained at the Clarence Works in England, is considered as a good one, though a higher ratio nearer to 1 has been realized. The higher this ratio the most economically as to fuel is the furnace working for a given ore; the higher it is the greater also is the specific gravity of the gases. Were it that of air, 1 cubic meter would weigh: 1.294 kilogram. As it is, we may assume in the following calculations 1.30 kilogram per cubic meter of gases as approximately sufficient.

Experiments were made at Seraing on the heating capacity of these gases. Specimens were collected *every day* during fifteen consecutive days, from 6 a. m. to 6 a. m., in vessels of 10 liters capacity, and tests made by Mr. A. M. Witz gave about 997 calories per cubic meter as the average result. This gives, at 1.30 kilogram per cubic meter: 1314 thermal units per pound (assuming 950 calories); the figure adopted by Mr. Greiner was 1296 thermal units per pound; Mr. Uehling takes the figure, 1,283.9 thermal units per pound, which is very close. Mr. Thomson, by assuming, as builders of engines do, 10,000 thermal units per horse-power-hour at 25 per cent efficiency, and amount of gas required would come to the same figure, very nearly.

As to the amount of gas per ton of iron smelted, Mr. Greiner gives: 13,365 pounds per ton of iron; Lowthian Bell gives for the Pittsburg district, 11,200 pounds (blast 593° C., coke 1882 pounds); for the Clarence Works, 13,347 pounds per ton of iron (blast 704° C., coke 2240 pounds[4]); Mr. Uehling gives, 10,589.62 pounds, which is very close to the figure of the Pittsburg district, and a more conservative one.[4]

Hence, per ton of iron, we have, adopting Mr. Uehling's figures, 10,589.62 pounds $\times$ 1283.09 thermal units $=$ 13,587,330 thermal units per ton of iron: as this corresponds to the lowest figure for weight of gases per ton of iron we will adopt it. If we take 13,347 pounds gas per ton (of the Clarence Works), and 1283.09 thermal units per pound, we come to 17,122,201 thermal units, and this corresponds to a consumption of coke of 2240 pounds per ton of iron (ton for ton) and a temperature of blast of 704° C. If we take 11,200 pounds gas per ton of iron, and again 1283.09 thermal units per pound, we come to: 14,369,600 thermal units per ton of iron, and this corresponds to a consumption of 1881 pounds of coke per ton of iron.

Mr. Thomson says: "The average practice in coke consumption is probably very close to 2240 pounds per ton, yielding 14,000,000 B. T. U. in waste gases." This is more than the figures adopted by Mr. Uehling, and nearly that corresponding to a consumption of 1881 pounds of coke only per ton of iron. It is true Mr. Thomson adds that a figure as low as 1700 pounds of coke per ton of iron has been obtained (with dry air by Mr. Gailey) in which case he assumes that the amount of gases would be considerably smaller, and consequently the total number of thermal units, which does not necessarily follow. But this smallest figure for coke is so far exceptional, and will be so, at least for some time to come, it being due to modifications in the working of blast furnaces, which necessitate particular additional machinery, a practice not generalized yet. Until it has become so the average practice in coke consumption may be retained at one ton of coke per ton of iron, and even 1881 pounds (0.82 ton), and still the heat contained in the gases will be found to approximate 14,000,000 B. T. U., or the figure of Mr. Uehling, 13,587,330 B. T. U.

We will remark here in passing, that if we adopt 11,200

[3] Paper by A. Greiner, Iron and Steel Institute meeting, London, May 5, 6, 1898.

[4] Special volume Iron and Steel Institute in American in 1890, page 171.

pounds of gases per ton of iron, and the 14,000,000 B. T. U. of Mr. Thomson, corresponding to 2240 pounds of coke, we come to a heat capacity of 1270 B. T. U. per pound of gas, that is practically a figure already mentioned.

Hence, in short, and so far as the present good ordinary practice of blast furnace goes, we can count on an amount of at least 13,587,330 B. T. U. in the gases per ton of iron, and on a heat capacity of 1283 B. T. U. per pound (Uehling, corroborated by other tests). As 1 hp.-hour = 2545 B. T. U., and that a gas engine is now guaranteed to give 25 per cent efficiency, this corresponds to, say, 10,180 B. T. U., 10,000 B. T. U. in round numbers, per effective hp.-hour, so that with such gases we would require $10,180 \div 1283 = 7.92$ pounds gas per hp.-hour, or, say, 8 pounds in round numbers. At Seraing direct experiments made with a 200 hp.-motor showed a consumption of 4 kgs. (8.80 pounds) of gas per effective hp., with the prospect that with a large motor (said Mr. Greiner) this figure would be much lowered; this makes it close to the 8 pounds mentioned above.

In the volume of the Iron and Steel Institute (special volume 1890) calculations of the horse-power required per ton of iron per hour for blowing purposes, show for the Isabella, Edgaro, Thomson, Lucy and other furnaces, such figures as 150 hp. to 160 hp and 187 hp., and as low as 130 hp. if we assume 10 per cent (Mr. Thomson's figure) for "auxiliaries," pumps, hoists, etc., we come to 175 hp. to 200 hp., and if we call it 200 hp., as Mr. Uehling does, this will cover the cases of higher pressures (higher than 10 pounds) now resorted to in certain furnaces. If, again, we add 50 hp., as Mr. Uehling proposes, for all auxiliary power, "as the tendency is to replace by machinery the hand labor," we come to an ample allowance of 250 hp. per ton of iron per hour; with an efficiency for gas engines of 8 pounds of gases (7.92 pounds) per effective hp.-hour; these 250 hp. represent $250 \times 8 = 2000$ pounds of gas for this purpose. The total amount of gases per ton being 10,589.62 pounds (Uehling), this corresponds, in round numbers, to practically 19 per cent of the volume of the gases for blowing in and compression. Mr. Thomson (gas engines) takes the figure of 20 to 25 per cent, counting the "auxiliaries." This is quite close, and probably 22 to 23 per cent ought to cover all possible cases.

Mr. Uehling gives for *heating* the blast, 1,884.38 pounds of gases. This is, again, nearly 19 per cent of the total weight. Mr. Thomson assumes 18 to 33 per cent; obviously this depends on the temperature at which the blast is blown in the furnace. At the Clarence Works (England) the temperature was 704° C., while at the Pittsburg works it was only 593° C., and, in some furnaces it is even lower, so that one figure may be just as correct as the other. If we take the average we come to 25 per cent of the total gases to heat the blast.

Twenty-three per cent to compress the blast, and 25 per cent to heat it, give us a total of 48 per cent, or, say, in round numbers, 50 per cent, and we could count thus on 50 per cent of the total amount of gases as likely to be available for other purposes than the requirements of the blast furnace. Mr. Thomson[5] gives 52 to 42 per cent as available surplus, an average of 47 per cent, as the figures are given; and we can see that, to all purposes, starting from different points of view, we come very nearly to the same results.

What will make the calculations based on the preceding data differ widely, is that Mr. Thomson, assuming 52 per cent, a figure based on Table I, page 96, as available surplus, applies it to the amount of gases corresponding to an expected normal future average consumption of coke per ton of iron of 1700 pounds (0.773 ton), while he states that the average normal consumption is now 2240 pounds, ton for ton, or thereabout. We do not contest the possibilities of the future, but we believe that we are authorized to say that, for the present at least, and for some time to come, the figures based on these anticipated results, legitimate as they may be, are ultra-conservative now. But, far from taking exception from them, as we have said, taking them such as they are, they show, even in the best possible conditions of blast furnace practice in the future, what could be expected of this utilization of about half the heat of the blast furnace gases in gas engines.

We will take such of the figures of Mr. Uehling, which, as it has been seen above, are corroborated and agree with those of Mr. Thomson for an assumption of 1 ton of coke per ton of iron, and not too high a temperature of blast, viz.:

10,589.03 pounds of gases per ton of iron.

1,283.09 B. T. U. per pound of gas giving 13,587,330 B. T. U. per ton.

1 hp.-hour = 2545 B. T. U., and an efficiency of 25 per cent for gas engines.

That is to 7.93 pounds of gas per effective hp.-hour. Mr. Uehling adopts 1,884.38 pounds of gas to heat the blast per ton, corresponding to about 19 per cent of the whole amount of gases. This leaves 8,705.25 pounds of gas available, corresponding to 1,097.76 hp. per ton of iron per hour. Subtracting 250 hp. required for blowing in and compressing the blast and auxiliaries, corresponding to about 19 per cent of gas, Mr. Uehling arrives at "847.76 hp. for sale or available for other purposes for every ton of iron produced per hour."

If we assume, as explained above, as an average of Mr. Thomson's figures, 25 per cent of the total amount of gases for heating the blast, and some 23 per cent, as an average, for the blast engine and auxiliary power, this gives us some 48 per cent of gas as necessary for the blast furnace plant with gas engines, leaving a surplus of 52 per cent. $0.52 \times 13,587,330$ B. T. U. = 7,065,411 B. T. U., and since we can assume with gas engines 10,000 per guaranteed hp.-hour, this gives us 706.54 hp. available as surplus per ton of iron per hour.

Mr. Thomson, for a consumption (as an average practice now) of 2240 pounds of coke per ton of iron, assumes as total amount of heat contained in the gases per ton, 14,000,000 B. T. U., and adds in the article quoted that improvements in gas stoves and gas engines permit the use of the larger figure given in his Table I, page 96, that is, as given, 52 per cent as surplus of gas available:

$0.52 \times 14,000,000$ B. T. U. = 7,280,000 B. T. U., and

$7,280,000$ B. T. U. $\div 10,000 = 728$ hp. as available per ton of iron per hour. But if, anticipating the future based on some results recently obtained in particular conditions in one case, he assume 1700 pounds of coke per ton of iron as a normal figure, then the heat contained in the gases, "*he says*," is reduced to 9,000,000 B. T. U. per ton, which gives him, adopting as a surplus his figure of 52 per cent "*the larger figure*" as given in his table:

$9,000,000 \times 0.52 = 4,680,000$ B. T. U., corresponding to 408 hp. per ton of iron made per hour, as available surplus.

Mr. Thomson adds, however (page 97) that "with poorer ores and in other unfavorable conditions the coke per ton of iron may reach as high as 2800 pounds, in which cases the heat contained in the gases per ton will reach 18,000,000 B. T. U." This is almost the figure at the Clarence Works, as quoted by Lowthian Bell in the volume of the transactions of the Iron and Steel Institute, based on the weight of gases given.

But here we may be allowed to call the attention to an oversight of Mr. Thomson, which changes the results he gives to much better figures, whatever he may assume for the total heat of the gases per ton, let it be 14,000,000 B. T. U. or 9,000,000 B. T. U. Indeed, referring to his Table I, page 96, of the article quoted, we read:

	Gas Engines.	
	%	%
Heating the blast	18 to	33
Compressing the blast	16.5 to	20
Auxiliaries	3.5 to	5
Surplus available	52.0 to	42
	100	100

[5] Table I, page 96 (gas engines) ELECTROCHEMICAL AND METALLURGICAL INDUSTRY, Vol. III, No. 3.

But the first three items, "heating" and "compressing the blast" and "auxiliaries," as quoted by him, represent only 38 per cent, so that the real surplus available from his calculations is not 52 per cent to 42 per cent, but 62 per cent to 42 per cent (an average of 52 per cent) and should read so. Considerations which he explains further (page 97) "may permit," he says, "the use of 'the larger figure' given in Table I as the percentage of surplus gas available in gas engines." We have thus to adopt this corrected figure, 62 per cent, instead of 52 per cent, which gives for 14,000,000 B. T. U. heat of the gases $\times$ 0.62 = 868,000 B. T. U., corresponding to 868 hp., instead of 728 hp., for 2240 pounds coke per ton of iron, and for 9,000,000 B. T. U., based on a hoped-for normal reduced consumption of 1700 pounds.

9,000,000 B. T. U. $\times$ 0.62 = 548,000 B. T. U., corresponding to an available surplus of 558 hp. per ton-hour, instead of 468 hp.

The production of pig iron in the United States for this years is estimated to 20,000,000 tons, or thereabout, which gives 2280 tons per hour.

At a surplus of 847.76 hp. per ton-hour (Uehling) we come to a total per hour for 2280 tons of 1,932,892 hp. At our figure of 700 hp. surplus, to 1,596,000 hp. At Thomson's figure for 14,000,000 B. T. U. in the gas, viz: 728 hp. to 1,659,840 hp. per hour, and for 868 hp.-hour per ton (the above figure of 728 hp. corrected for 62 per cent surplus of gases, instead of 52 per cent) we come to 1,959,040 hp. At Mr. Thomson's figure of 468 hp. per ton-hour (corresponding to 9,000,000 B. T. U., consumption of coke 1700 pounds) we come to 1,067,040 hp. per hour. At the same figure, 468 hp. corrected to 558 (for surplus of 62 per cent of gases, instead of 52 per cent), we come to 1,272,240 hp.-hour.

Hence, we can legitimately count, taking Mr. Thomson's figures as they stand, in the best possible future conditions of blast furnace practice *and of ores*, on at least one million of horse power per hour, and, with his own figures corrected on 1,272,240 hp., as available power to generate electricity, and for some time to come on at least 50 per cent more, if not double this amount in many furnaces.

In fact, such calculations should be made *for "each particular"* furnace, according to the coke consumption per ton of iron, temperature of blast and amount of gases resulting per ton, factors which necessarily vary with the quality of the ores smelted. As a minimum possible, we can depend on at least 1,000,000 hp. per hour of surplus available power.

The importance of this utilization of blast furnace gases for generating power available for electrometallurgical purposes is such that it may not be considered foreign to our subject to examine briefly the objections which have been raised against it, and the answers, based on practice, which have been made by eminent metallurgists.

As to the heat capacity of these gases, and their adaptability to be used in gas engines, they are not any longer contested:

First, one of the drawbacks brought forward has been the dust they carry with them.

The gases at Seraing are certainly not cleaner than at any other works; the contrary is true, owing to the kind of ores smelted. Calculations made by Mr. Greiner, based on repeated experiments, show that the gases supplied to the gas engine (200 hp. motor), freed from such dust, as they are in all cases when supplied to the boilers at these works, did not contain more than 2 grams of impalpable powder per cubic meter. At this figure of 4 cubic meters of gases per hp., a 200-hp. motor would absorb 40 kgs. of dust per day. This dust, says Mr. Greiner, was given out almost completely as a light white cloud, as proved by the fact that, after a run of four months, it was not found necessary to clean the cylinder of the motor, and Mr. Greiner adds, where are the boilers, heated by blast furnace gases, which can run four months without cleaning?

Second. As to the destructive action on metal of these gases, owing to the sulphuric anhydride, chlorine, phosphoric acid, the dust may contain, analyses show such an amount of alkalies, lime, magnesia, alkalies soda and potash that this corrosive action was certainly counteracted. At any rate, by a simple washing not requiring necessarily a large amount of water, they were able at Seraing to run a motor (200 hp.) for two years, without any observable corrosion of the cylinder.

Third. Objections to the irregularities in the composition of these gases have not been found to be serious, as it might have appeared a priori; first, because gas engines accommodate themselves to gases of different composition, and experience shows that such cases occur when the furnace is working badly, and a furnace must be working exceedingly badly when the gases, in these conditions, cannot be lighted. At any rate, if the furnace is working so badly as to produce non-inflammable gases, the same trouble will certainly prevail with boilers heated by these gases, as with the gas engine, and in such cases in the same manner as coal or coke is burnt on grates under the boilers during such temporary derangement, as Mr. Greiner remarks, an emergency gas producer could feed the gas engine. M. Thomson has very wisely remarked that this objection, if it exists, could be easily remedied by grouping together two, three or more furnaces without even the use of a gas producer.

Fourth. As to the speed of the gas engines operating the blowing cylinder, says Mr. Greiner, if it were an object when the gas motors were small, and their speed high, the large motors of 2000, 3000 hp. and more are running now at such speed as cannot be objectionable with our modern blast engine. In Mr. Gailey's run, the blowing engine was running at 100 to 114 revolutions per minute.

The advantages of gas as a source of power are obvious. Beside the economy of running of the machine as compared to that of engines supplied with steam, gas can be transmitted at any distance by piping, almost without condensation in the flues, as is the case with steam, without any appreciable loss of head, without any pressure, and such piping is comparatively simple and cheap. The use of gases supresses the boilers and their attendant drawbacks, and suppresses cumbersome masonry. It may be added that a gas motor can, at will, supply heat, light or power.

Mr. Thomson has examined the details of the cost of an installation of such a gas motor plant, utilizing the blast furnace gases, and has given estimates which we have not to consider in this article, his competency on such matters being well known. We will retain only his very conservative estimate of surplus, assumed, as we have said, in the most favorable conditions possible of work of the blast furnace, and realized only so far, but exceptionally, the figure 468 hp. per ton-hour in order to show the possible gain were this power to be applied even to the direct electric smelting of iron from its ores.

We have seen that 200 hp., as the power required for the electric smelting of 1 ton of pig iron per day, is not a too favorable figure; this corresponds to 4800 hp. per ton-hour. Hence the surplus of power over all the requirements of the blast furnace represents the possibility of smelting electrically an additional amount of pig iron per hour of about 10 per cent of the present production. Were we to take Mr. Uehling's figures, we would come to an increased production in metal of 20 per cent. These figures speak for themselves. Applied to the manufacture of electrical steel by the open-hearth process, to that of special steels, etc., this wasted surplus of energy, even utilized but in part, opens possibilities of which we desired in this article to show the importance.

We give below a table resuming the calculations which we have examined above.

References.

Hubert, Ingenieuer au corps des Mines de Belgique. De l'utilization de gaz des haut fourneaux pour la production de

	Heat Value of Gases, Thermal Units, per lb.	Weight in lbs. of Gases per Ton of Iron.	Total Amount of Thermal Units in Gases. 1 lb.—1,283 B. T. U.	Percentage of Total Amount of Gases Used.				Net Horse-power Surplus With Gas Engines Over All Requirements of the Blast Furnace.	
				For Compressing Blast and Auxiliaries.	For Heating the Blast.	Totals, Per Cent.	Surplus, Per Cent.	Per Ton Hour.	Per Hour for 2,280 Tons Estimated Production of Pig Iron in 1905.
	Th. U.	Lbs.	Th. U.	%	%	%	%	H.P.	H.P. per hr.
Luermann	1,220	....	.....	.....	.....	.....	.....	.....	.....
Greiner (Seraing) Coke 2,240 lbs., per ton of iron	1,314	13,365	16,858,620	.....	.....	.....	.....	800	1,824,000
Uehling	1,283	10,589	13,587,330	19°	19	38	62	847.96	1,932,392
LowthianBell(Clarence Works) Coke 2,240 lbs, Blast 704° C	.....	13,347	17,122,201	.....	.....	.....	.....	.....	.....
Lowthian Bell (Pittsburgh Works), Coke 1882 lbs., Blast 593°C.	.....	11,200	14,309,600	.....	.....	.....	.....	.....	.....
Thomson on a basis of 2,240 lbs. Coke, assuming fig. Table I, Surplus 52%	.....	.....	14,000,000	20 to 25	18 to 33	38 to 58	52 to 42 as given	728	1,659,840
Thomson, same basis, 2,240 lbs. Coke, assuming corrected fig of Table I, viz., 62%.	.....	.....	14,000,000	20 to 25	18 to 33	38 to 58	62 to 42 as corrected	868	1,959,040
Thomson, Coke 1,700 lbs., assuming fig. of Table I, 52% Surplus	.....	.....	9 000,000	.....	.....	.....	52% as given	468	1,067,000
Thomson, Coke 1,700 lbs., assuming corrected fig. of Table I, 62%	.....	.....	9,000,000	.....	.....	.....	62% as corrected	558	1,272,240
Assuming 2,240 lbs. Coke, Average of 50% of Surplus	.....	.....	14,000,000	.....	.....	.....	50%	700	1,596,000
Calculated from Mr. Gailey's data in his dry air run. Blast 465° C., Gas 191°C. Coke 1,726 lbs. per ton of iron, average.	.....	11,284	14,477,372	.....	.....	.....	50%	724	1,610,720

la force motrice.—*Annales des Mines de Belgique*, 1897, tome II.

Lüermann, Stahl und Eisen, March 15, 1898, page 158. Heat value of blast furnace gases. Paper read at the general meeting Assembly of German Metallurgists, Düsseldorf, February 27, 1898.

Thwaite, Note on the utilization of blast furnace gases. *Iron and Coal Trade Review*, November 16, 1894, May 6, 1898, page 24.

Stahl unde Eisen, March 15, 1898.

Greiner, General Director of Cockerill Co., Seraing, Belgium. Paper read at the annual meeting of the *Iron and Steel Institute*, London, May 5 and 6, 1898.

Lowthian Bell, etc., the *Iron and Steel Institute* in America. Special volume, 1890.

A. Pourcel, Génie Civil, XXXIII, No. 3, 1898. On the Utilization of Blast Furnace Gases in Gas Engines.

A. Dutreux, Utilisation directe des gaz des Haute fourneaux dans les Moteurs a explosion. *Génie Civil*, 1898.

Prof. Watkinson, West of Scotland, *Iron and Steel Institute*, March, 1895.

Engineering, May 13, 1898.

F. duP. Thomson, ELECTROCHEMICAL AND METALLURGICAL INDUSTRY, March, 1905.

CALCIUM CARBIDE DUTY FREE IN CHILI.—By a recent law calcium carbide has been placed on the free list in Chili. The intention of this law is to so cheapen the cost of the production of acetylene gas as to make it a practicable illuminant for the numerous estates and small centers of population for which illuminating gas and electricity are not feasible.

RECENT METALLURGICAL PATENTS.

ROASTING.

T. Huntington and F. Heberlein (786,814, April 11) divide the roasting of sulphide ores into two portions. First, a preliminary roast with access of air, until the proportion of sulphur is reduced to 12 per cent. Then the temperature of the ore is suddenly cooled by means of water; the temperature is thereby reduced to that of atmosphere, some sulphatization is effected, and the anhydrous sulphates of the metals combine with their water of crystallization, so that $ZnSO_4$ becomes $ZnSO_4\ 7Ag$; $CuSO_4$ becomes $CuSO_4\ 5Ag$, etc. Then follows the second roasting process, whereby the water-cooled material is placed in a receptacle in which it is reheated and through which a current of air is caused to pass. In order to start the necessary combustion, a layer of hot fuel or of hot ore containing sulphur is placed in the bottom of the receptacle. The current of air assists and augments the heat thus furnished, with the effect that the sulphur is oxidized and sulphurous-acid gas is given off until the desulphurization of the ore is complete. The material is then ready for treatment in the blast furnace.

H. M. Heath, G. Morrice and R. L. J. Gruss (785,067, March 14) patent a modification of the process of roasting auriferous ores containing sulphur or arsenic ("sulphurets"), preliminary to the chlorination process for the extraction of the gold. If the sulphurets are roasted with access of air, a temperature of 1,200° F. is required, and the treatment requires considerable time. The inventors propose to carry out the roasting process not in presence of air but of oxygen.

Under these circumstances a temperature of 600° F. only is needed, and the time of treatment is considerably reduced. The inventors use a roasting furnace with a vertical flue of sinuous or zigzag form, through which the auriferous ore passes downwards, while oxygen is passed upwards from an oxygen-generator connected to the lower terminal of the flue.

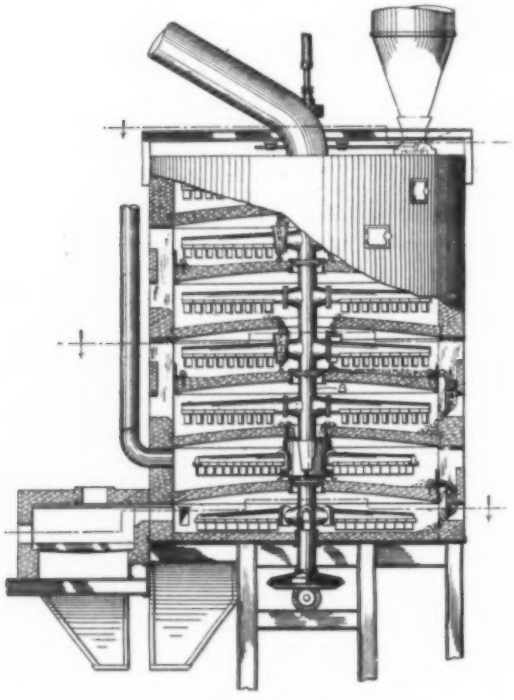


FIG. 1.—ROASTING FURNACE.

C. H. Repath and F. E. Marcy (patent 785,437, March 21, assigned to Frank Klepetko) patent a modification of the McDougall furnace for roasting zinc blende. The furnace is shown in Fig. 1. The object is twofold: to oxidize all the ore without loss, and to save the sulphurous anhydride formed during the operation. The loss of ore in ordinary furnaces is mainly due to the upward draft of gases which carries the fine particles of ore with it. To prevent this, the inventors cause the ore to slide from one hearth to the next below, instead of letting it drop through space and encounter the upward draft of the gases. The sliding of the ore assists the action of the rakes. The upper four hearths are provided with two rabble-arms each, the sixth and seventh with three rabble-arms, in order to increase the stirring and discharge rather on one side of the furnace. The construction of the furnace is described in detail.

Wet Processes.

An agitator for use in the cyanide process is patented by E. Stevens (784,598, March 14). Its construction is shown in Fig. 2, which is self-explanatory. The gold-carrying materials are placed within the bottom of the funnel at the lower end of the apparatus, and the cyanide solution is added. By revolving the shaft 13, which carries a screw, 14, the materials are raised inside the cylinder which surrounds the screw. Arriving at the top, 21, of the cylinder, the materials spread out and glide down the inclined upper surface, 20, of the cone around the cylinder. The materials then fall to the bottom, and are again carried upward inside the cylinder, etc. While being spread out upon the conical surface at the top, the pulp is exposed directly to the air. "Where potassic cyanide is employed, as is usually done, the cyanogen appears to be set free in its nascent state upon the upper surface of the spreader, which is, of course, always above the level of the solution. The cyanogen thus being set free, and having intense chemical activity, owing to its nascent state, unites with the gold, with the result that a much larger proportion of the metal is saved, or that with a given ore a weaker cyanide solution may be employed." It has, of course, long been known that the presence of air is essential for dissolving gold in cyanide solution.

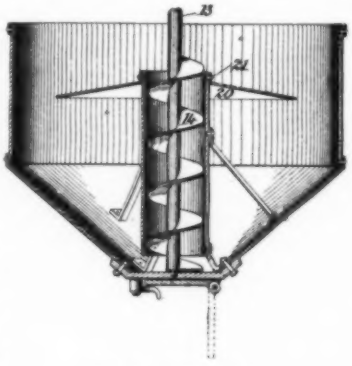


FIG. 2.—AGITATOR.

G. A. Duncan (787,878, April 18) patents a treatment of slimes by filtering. The essential point is that the slimes are accumulated on the exterior of a filtering cell by suction from the interior of the cell while the latter is immersed in the slime-bearing liquid. The supply of this liquid is then cut off and a metal-solvent liquor is introduced, and is sucked through the slimes, etc.

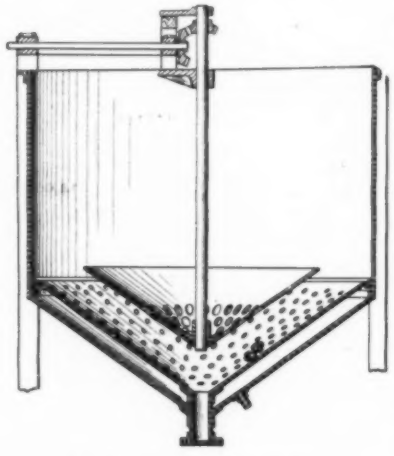


FIG. 3.—AGITATOR AND FILTER.

V. A. Robinson (785,522, March 21) patents the ore agitator and filter shown in Fig. 3, in which 8 is a foraminous supplemental bottom, which acts as a filtering medium; above the same is a perforated inverted-cone-shaped agitator. By revolving it a continuous systematic agitation is produced, whereby the filtering medium, 8, is kept free from clogging. The material in the inner inverted-cone-shaped agitator is continuously carried upwards, flows over and passes downwards between the outer surface of the agitator and the inner surface of the filtering surface. Through the perforations in the surface of the agitator it enters again into the latter and so on, until the process is completed.

B. Hunt (786,441, April 4) patents a gravity filter for extracting liquids from granular or comminuted material. This material is arranged in pyramidal form, of sufficient height to cause its compression by its own gravity. The inventor provides means for removing from the base of the column, by mechanical appliances, a quantity equal to that supplied at the top, so that the head and pressure will remain approximately uniform. He also provides a series of inwardly-inclined surfaces, or arresting devices, attached to the inside walls of the retaining chamber, whereby the filtering material is retained, and water exuding from the mass is directed away from the same and through the filtering medium.

On account of limitations of space a large number of patents had to be held back, which will be covered in our next issue.

Notes on Electrochemistry and Electrometallurgy in Great Britain.

(From Our Special Correspondent.)

METALLURGICAL PAPERS OF THE MONTH—METALLURGY OF GOLD.

The February meeting of the Institution of Mining and Metallurgy by no means exhausted the subject of the paper by Messrs. A. Jarman and E. Le G. Brereton of the use of ammonia compounds in cyaniding cupriferous ores. At the March meeting a supplementary paper on this subject entitled "Note on the Ammonia-Copper-Cyanide Process" was presented by Mr. H. Livingstone Sulman. In no sense did Mr. Sulman treat the previous paper in a hostile spirit, but tendered his suggestions with the object of rendering it even more complete.

In investigating the solubility of gold in various cyanide and other solutions, in 1893, the author discovered a number of solvents of greater or less power; amongst the most rapid and efficient of these were solutions which contained an alkaline cyanide mixed with certain equivalents of ammonia, and of a cupric salt.

Such a solution when freshly prepared formed a gold solvent of much greater rapidity than ordinary potassium cyanide, indeed approaching that of bromo-cyanide; but its application was accompanied with a comparatively rapid loss of solvent power, and with the deposition of sparingly soluble crystals, containing ammonium, copper and cyanogen. Mr. Sulman endeavored to trace the reactions involved, but, not then recognizing their applicability to the treatment of oxidized cupriferous gold ores, he abandoned the ammonia-copper-cyanide type of solvent for simple gold ores by reason of its instability. The present note cannot, therefore, in any way detract from the priority of the several metallurgists who have since made the ammonia-copper-cyanide process for the extraction of gold a more or less successful one.

After describing in detail the various reaction, and discussing the effect of the instability of cupric cyanide and the varying compositions of the hydrated cupric-cuprois-cyanide, the author surmises his view of the process in the following terms.

"Owing to the complexity of the reactions, it is difficult, if not impossible, to formulate any simple chain of reactions as is held to explain the solution of gold by simple alkali-cyanide in presence of oxygen; it is still further complicated by the probable formation of other metallic cupro-cupric-cyanides, such as those of iron, etc. But it seems evident that the broad explanation of the ammonia-copper-cyanide process is dependent not on the solvent action upon gold of potassium cyanide, nor of ammonium cyanide, whether combined with copper cyanide or not, plus oxygen, but upon the formation of ammonium-cuproso-cupric cyanides of the cuprammonium type, which, gradually yielding up some portions of their cyanogen contents, act as powerful solvents for gold until their limits of stability and solubility are reached, without the necessary intervention of oxygen. When they reach this limit they cease to act as solvents ,and tend to separate out in the crystalline form noticed by the authors.

"These compounds, either in solution or as crystals, are broken up on heating with lime or other fixed alkali yielding ammonia and a solution of alkaline or of alkaline-earth cyanide, whilst cuproso-cupric hydrates, contaminated with more or less cuprous cyanide, are left as precipitate. The form in which the gold is dissolved in the above reactions, therefore, also differs from that of the ordinary cyanide process, as there is no uncombined alkaline cyanide present necessary to produce an alkaline aurocyanide. It is probable that the gold is converted by nascent cyanogen into simple aurous cyanide, which is readily soluble in any slight excess of ammonia and ammoniacal salts.

Messrs. Jarman and Brereton's conclusion is "that an ammoniacal cupriferous cyanide is produced of low solubility, having the property in common with copper potassium cyanide, that the copper in it is replaceable by gold—(i. e., in part.)" I think, however, it will be clear that whilst an ammonium cupriferous cyanide is responsible for the solvent action, it is not of the copper-potassium cyanide type referred to by the authors, but a cuprammanium cyanide containing no cyanogen combined with alkali metal. Further, it appears that the gold is not dissolved by replacing copper, but that this takes place by virtue of nascent cyanogen derived from the cupric cyanide of the cuprammonium compound. That copper is deposited whilst the dissolution of the gold proceeds is undoubted, but this is due not to replacement of copper by gold, but the formation of increasingly insoluble cuprammonium cyanides from the break-down of the cupric cyanide radicle with loss of cyanogen. Though this cyanogen is the cause of gold dissolution, it might equally well be used up in other reactions, with the continued deposition of the green ammonium dicuproso-cupric cyanide crystals. Messrs, Jarman & Brereton have hitherto dealt only with the question of oxidized copper in gold ores; the question of copper in pyritic or unoxidized gold ores is a problem of even greater commercial importance, although, apparently, correspondingly complex. The formation of cuprous sulphocyanide, which, becoming more insoluble as the alkaline cyanide contents of the liquors fall, is thus precipitated in the sands, is, I believe, to a considerable extent, the cause of cyanide losses in the treatment of ores containing copper sulphides."

While Mr. Sulman's paper called for such extensive quotations as has been accorded to it, the other paper by Mr. Gustav Köller on the Kedabeg Copper Mines, although much longer, does not lend itself to this treatment. It is not easy to abridge concisely some 38 8-vo. pages which are devoted to an historical account of the undertaking, and to the geological and metallurgical summary of the mines. As a contribution to the bibliography of copper mining, the paper as a whole is of great value and much interest. It may be mentioned, however, only about one-sixth of the copper is refined electrolytically.

THE METALLURGICAL SIDE OF THE LIEGE EXHIBITION.

A modern exhibition without some meeting of scientific societies will only bear comparison to the eating of an egg without salt, or to another standard for things that are inane, of which one of Mr. Kipling's characters speaks startlingly. An international congress of mining, metallurgy, mechanics and applied geology is to be held at Liege from the 26th of June to the 1st of July. An influential organization has been appointed. In addition to the inaugural meeting, the congress will comprise: (1) General meetings; (2) section meetings, devoted to the special discussion of questions relating to mining, metallurgy, mechanics, and applied geology; (3) lectures; (4) visits to the exhibition, to various scientific or industrial establishments, and applied geology excursions. The provisional programme of the second or metallurgical section comprises papers on the following subjects: (1) Utilization of Non-Caking Coals for Making Coke; (2) Study of the Blast Furnace; (3) Influence of Foreign Substances on Pig Irons and steels; (4) Methods for Intercepting Dust from Blast Furnace Gases, with a View to Their Utilization; (5) Slag Bricks and Cements; (6) Utilization of Poor Gases, with a View to Producing Power for Driving Roll-Trains; (7) New Methods for Making Open-Hearth Steel; (8) Special Steels; (9) Forging by the Press and Steam Hammer—Hardening and Annealing; (10) Electro-Metallurgy; (11) Metallography.

The Institution of Mechanical Engineers is also holding a meeting at Liege shortly before the congress mentioned. The list of papers to be read has not yet been announced, but it is probable that several will be of a metallurgical nature.

Market Quotations.

In the chemical trade prices have been generally stable, particularly in the case of the alkaline products. Shellac seems to have ceased falling and to have taken an upward turn, the quotation now standing 147s. per cwt., as against 140s. a month ago. Copper sulphate has fallen 15s. to £22 per ton, while cyanides (98 per cent. minimum) are ½d. per pound cheaper at 7½d.

Para rubber is still in good demand, with firmer prices. Platinum is unchanged. Cleveland pig iron which fetched over 50s. at the beginning of the month has closed at 49s. 2d. Copper has also fallen since the middle of the month (when it was just under £69 per ton) to £67.17.6. Tin has advanced in a very striking manner to £137.10.0, chiefly due to a report that the Banca production would not come up to anticipations. A rise of £6.5.0 is indeed unusual. Lead remains at practically last month's closing price, although a rise is expected. Quicksilver is unchanged.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Electric Furnaces and Furnace Products.

Electric Furnace.—W. C. Arsem, Schenectady, Assignor to General Electric Co. Patent 785,535, March 21, 1905. Application filed Aug. 12, 1904.

The furnace is intended for heating materials to a high temperature in a vacuum or an atmosphere of any gas. It consists essentially of a vacuum chamber of gun metal, coated with tin to prevent leakage through the pores of the metal. A cylinder of refractory but conducting material, such as graphite, is suspended from the cover of the gun-metal vessel by U-shaped tubular conductors. This graphite cylinder is brought into the form of a tubular helix by cutting a helical slot into it. It is provided at both ends with suitable graphite terminals, and a carbon standard is placed in its interior, which is intended to carry the crucibles or other articles to be heated. A box of refractory material is placed around the heating tube, the space between them being filled with pulverized graphite. The conductors which lead to the tube are made hollow for the purpose of circulating water through them, so as to keep them cool. Means for exhausting the air from the chamber or introducing any desired gas are, of course, provided. Furthermore, the whole vacuum chamber is surrounded by a water jacket. It is stated that with this apparatus any temperature up to the vaporization point of carbon can be obtained and constantly maintained for any length of time at a pressure of 0.2 mm. or less. The apparatus may be used for the fusion of refractory substances, the reduction of metals from their compounds in an atmosphere free from oxygen, the preparation of alloys in vacuo or inert gas, etc.

Electrolytic Production of Metals and Compounds.

Apparatus for Effecting Electrolysis.—H. Philipp, Wyandotte, Mich. Patent 784,592, March 14, 1905. Application filed Aug. 10, 1903.

The apparatus is intended for the electrolysis of alkali chlorides, and belongs to the type of the mercury cells. As shown in central vertical section in Fig. 1, it depends upon the flow of the mercury by gravity. It consists of a cylindrical vessel *A*, preferably made of earthenware, which is provided with a spirally-wound trough *B*, an inlet pipe c^3 and outlet pipe c^5. The mercury enters through pipe c^4 and flows out through pipe c^5. The cylindrical vessel is provided with a cover *c*, which rests in a water seal *d*. Introduced through an aperture in its top is the cylindrical carbon anode *D*, composed of carbon staves held together by rubber bands b^3, electrical connection being made with the terminal of the current by means of an iron ring *b* and rivets b^2. The cylindrical carbon anode *D* is filled with an alkali chloride, holes *e* being arranged to provide for a free exchange of the solution in both compartments. Electric wires in conjunction with an electromagnet *M* are arranged in the mercury inlet pipe so that the electromagnet will lift the valve *P*, and will only allow a certain quantity of metal to flow in a constant stream through the spiral trough so as to cover the bottom of the latter to the necessary depth. Conducting wires *a*, placed at various points along the path of the mercury, are connected to the negative terminal of a source of current, and thus constitute the flowing sheet of mercury, the cathode of the apparatus. The gutter is so inclined horizontally that the centrifugal action of the mercury is counteracted, and an exact and even depth of the moving cathode is assured. The gases generated during electrolysis pass off at the outlet *c*, while the amalgam escapes through a pipe c^6, furnished with a tripping valve *S*, which will withstand the action of the solution, but will lift when the specifically heavier mercury strikes it. One of the advantages claimed for the apparatus is that the flow of mercury is automatically interrupted as soon as the current is cut off, and the apparatus then empties itself of mercury, and the deleterious reactions upon the mercury, which are liable to happen in horizontal apparatus when the current is cut off, are thus prevented.

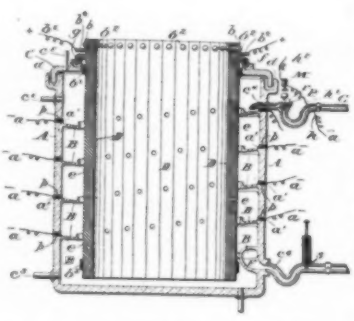


FIG. 1.—ELECTROLYSIS OF SODIUM CHLORIDE.

Method of Treating Alkali Metal Amalgam.—C. E. Baker and A. W. Burwell, Cleveland. Patent 782,893, February 21, 1905. Application filed April 15, 1904.

The method depends essentially upon heating the amalgam in an atmosphere containing hydrogen for the purpose of forming a hydride of the alkali metal. Such amalgam, derived, for instance, from an electrolytic cell with a mercury cathode, is drawn into a suitable retort and heated in a hydrogen atmosphere until the mercury distills off, while the hydride of the alkali metal is substantially non-volatile at the temperature of vaporization of the mercury, and is left behind as a residue. The vapors of mercury may then be condensed and returned to the electrolytic cell. It is stated that the amalgam may be heated to a variable temperature, provided it keeps between the vaporization point of the mercury and the decomposition point of the sodium hydride. The inventors have found that the mercury distills off more freely by alternately raising and lowering the temperature of the amalgam between these limits. The mercury may be distilled in a current of hydrogen, if desired. The residual alkali-metal hydride is then heated to a temperature sufficient to decompose it with liberation of hydrogen, the resulting alkali metal being recovered. It is proposed

to employ a number of interconnected retorts, so as to operate the process without substantial loss of hydrogen, by absorbing in one retort the hydrogen produced by distilling the sodium hydride in another one.

Electrolytic Apparatus.—A. Wright, Brighton, England. Patent 782,308, February 14, 1905. Application filed March 23, 1903.

The invention applies specially to electrolytic apparatus, such as mercury electrolytic meters in which mercury is used as anode, and is intended to prevent the formation of deposits on the surface of the mercury or at the edges, where the mercury and the containing vessel meet. This formation is explained as being due to the stagnation of the mercury and the impossibility of realizing a washing action of the electrolyte in the ordinary type of apparatus. In order to get over this difficulty, it is proposed in the present apparatus to support the mercury constituting the anode, not by a solid support, but by a so-called "surface tension grid;" that is, a support having orifices and formed of material which is not wetted by mercury, so that the well known surface tension of the mercury is utilized. Such a grid may be made of platinum or platinum-iridium gauze or perforated platinum or platinum-iridium sheet or foil, or if spirally or otherwise bent platinum or platinum-iridium wire. They may also be made of spun-glass fabric. Platinum gauze with a hundred meshes to the linear inch is stated to give good results in practice, in the case of electrolytic meters. In other cases the general consideration of the gauze to be employed is dependent upon the fact that the greater the depth of mercury on the grid, the shallower must be the orifices, and the greater the vibration to which the mercury is exposed, the smaller must be the orifices. When a grid is made of spun-glass gauze, its strength as compared with the weight of mercury to be supported must be carefully considered. The action of such grids is described as follows: When acting as a support for a globule or other mass of mercury, the grid is not wetted and the surface tension of the mercury is such as to prevent its flowing through the interstices of the grid. The effect is that instead of the upper surface of the mercury alone being washed by the currents set up in the electrolyte, the under surfaces and sides are also washed by reason of the electrolyte having access to the mercury at the orifices or interstices of the grid. Several constructions of mercury electrolytic meters embodying the above principles are described.

Process of Detinning.—F. von Kuegelgen and G. O. Seward, Holcomb's Rock, Va., assignors to Union Carbide Co. Patent 783,726, February 28, 1905. Application filed August 1, 1904.

The process depends upon the use of a solution of dry chlorine in a liquid which contains no moisture, based on the fact that dry chlorine, in marked contrast to wet chlorine, between certain limits of temperature acts on tin, but not on iron. The inventors have discovered that a solution of the dry chlorine in stannic chloride or other suitable anhydrous liquid removes the tin completely and rapidly from tin scrap dropped into it, while the iron is not attacked at all. Even if the iron were attacked, in the case of a stannic chloride electrolyte, it would form chloride of iron, which is insoluble in anhydrous stannic chloride. This advantage would also hold good if other metal were present in the tin scrap, as the anhydrous stannic chloride does not dissolve other chlorides. The stannic chloride containing the dry chlorine gas, by action upon tin scrap, reforms a new quantity of stannic chloride. The process is carried out by placing tin scrap in a closed vessel, so as to prevent moisture reaching the materials, and there subjecting it to a solution of dry chlorine in anhydrous stannic chloride. An excess of the chlorine should always be present. After the chlorination has taken place, a suitable quantity of dry chlorine is added and the quantity of new stannic chloride formed taken away. The removed stannic chloride may then be treated for the recovery of the tin by electrolysis or by chemical means. Though stannic chloride is preferable, any other liquid may be used which is capable of dissolving dry chlorine, and which contains no moisture.

Electroplating Device.—G. W. Clough, Cleveland. Patent 784,034, March 7, 1905. Application filed January 30, 1904.

The object aimed at in the invention is the construction of an apparatus for continuous electroplating of small articles. The apparatus consists of a rectangular vat, in which is situated, nearly half submerged, a rotating drum. Within this drum there is arranged a spiral carrier, which rotates with the drum and the turns of which form a continuous channel in the manner of an Archimedean screw, so that the articles to be plated, and which are introduced at one end, are gradually carried forward until they emerge at the other end. A spiral wire conductor is wound within the spiral turns of the carrier, so as to ensure continuous electrical contacts of the articles being plated with the cathode terminal of a source of current. Anodes, suspended from the shaft around which the drum rotates, supply plating metal to the fluid in the usual manner. In operation, the speed of the apparatus is regulated according to the thickness of deposit the articles are to receive, so that they are finished when they emerge at the discharge end of the cylinder. The vessel in which the electrolyte is contained is made of wood or other insulating material, and the drum is also preferably composed of wood or rubber.

Electroplating Apparatus.—L. Potthoff, Flushing, N. Y. Patent 786,776, April 4, 1905. Application filed Dec. 1, 1904.

The apparatus is intended for continuously galvanizing articles such as bars, pipes, etc., in large quantities. Upon the electroplating tank there is mounted a framework, which carries hangers at opposite ends of the tank, through which pass two shafts, having a sprocket wheel mounted on each of them. Chains or belts run around these sprocket wheels, upon which are mounted, at suitable intervals, wooden pins, of such shape as to cause round work, such as tubes, to roll when engaged by them. The work is rolled by the pins over longitudinal conducting bars, which form a sort of a track extending through the tank and which act as cathodes. The anodes are placed below the cathode bars. As the work is rolled by the pins over the conductor bars, the points of contact constantly change, so that all parts of the work receive a deposit.

GALVANIC ELEMENTS.

Galvanic Battery Cell.—A. T. Sanden, New York. Patent 784,125, March 7, 1905. Application filed December 15, 1904.

The battery belongs to the type of small cell used for being carried by persons by means of a belt or the like. It is compact, and the zinc element is made of a much thicker metal than used heretofore, and is corrugated, preferably longitudinally. A porous fabric divides it from the outer element, which consists of a plate or sheet of copper so folded as to bring its edges together and give it an ovoid form.

MISCELLANEOUS.

Apparatus for Hygienic and Therapeutical Purposes.—J. M. A. Lacomme, New York. Patent 782,400, February 14, 1905. Application filed September 3, 1903.

The apparatus is intended for the electrolysis of water or chemical reparations, so as to use the resultant gases for medical purposes in hospitals, schools, etc., for changing the atmosphere. It consists essentially of a glass cup, the lower part of which is filled with the liquid intended to be electrolyzed, while the upper part is perforated. Electrodes, the whole of which, with the exception of a small part at the lower end, is covered with a glass tube, dip into the liquid. One or more of these cups may be provided, each being a duplicate of the other. The electrodes are adjustable.

Composition of Matter and Process of Making It.—B. F. Gardner, Chicago.

The composition is intended to be used as a resistance material for use in heaters, rheostats, etc. It is made up of about 50 per cent graphite, 25 per cent carborundum, 20 per cent

rubber and 5 per cent sulphur; these proportions, however, being variable, according to the amount of electrical resistance the material is required to have. The carborundum, graphite and sulphur are mixed in a dry state and are then thrown onto the rubber, which has previously been reduced to a plastic condition by being passed through heated rolls. The rolling is continued until the mixture is thoroughly united with the rubber. The mixture is then calendered or molded into any suitable form and vulcanized, after which it is carbonized. This is done by burying it in sand and applying heat until all the sulphur is driven off and the rubber is carbonized. The carbonized material is very hard, dense and non-fusible, and retains the shape in which it has been molded.

Asymmetric Shunt for Direct-Current Electric Circuits of High Inductance.—W. S. Horry, Niagara Falls. Patent 782,134, February 7, 1905. Application filed October 29, 1904.

The arrangement consists of a main circuit, which contains an inductance, for example, an electric motor, which circuit can be opened or closed by a switch. A shunt circuit connects two points, one at each side of the inductance, with each other, which shunt circuit contains an asymmetric electrolytic cell, in order to allow the passage of the current carried by the main circuit, but to permit the passage of current in the opposite direction. The asymmetric cell consists of an electrode of aluminium, and one of lead in an electrolyte composed of an aqueous solution of potassium phosphate or citric or sulphuric acid. A modified arrangement is provided with a switch having an arc-shaped contact, by which, when it is in its normal position, the main circuit is closed, while the shunt circuit is open. When the switch is opened it first closes the shunt circuit and then opens the main circuit. This arrangement is desirable when the inductance must remain in circuit for considerable periods, as the asymmetric cell is normally out of circuit, and there occurs no loss of current or injury to the cell, which might be occasioned by slow or accidental leakage through it.

On acount of limitations of space a number of patents had to be held over for our next issue.

SYNOPSIS OF PERIODICAL LITERATURE.

A Summary of Articles Appearing in American and Foreign Periodicals.

Industrial Applications.

Precipitation of Gold from Cyanide Solutions.—A paper read by W. J. Sharwood last December, before the California Miners' Association, reviews the various processes by which precious metals may be precipitated from a cyanide solution, and deals especially with precipitation by electrolysis, by zinc shavings and by zinc dust. The zinc dust process is thought to be as well adapted as the electrolytic to the precipitation of low-grade slime solution. Some experiments were made on a solution carrying about $2.50 gold and $0.20 silver per ton, together with 0.015 per cent copper and 0.05 per cent free cyanide. One portion was treated with hydrogen sulphide until saturated; another was made distinctly acid and then allowed to stand until the recipitate of silver and copper cyanide settled, when it was filtered. Other portions were electrolyzed. It was found that precipitation was far from complete unless the current was allowed to act for a long time and unless the surface of the lead plates used was large in proportion to the volume of solution. When this was done all traces of the gold and silver and copper were removed. Other portions were agitated with zinc dust at the rate of one-quarter pound per ton, without filter-pressing and others filter-pressed. The results were as follows:

	Percentage of Contents Precipitated.		
Method of Precipitation.	*Gold.*	*Silver.*	*Copper*
Saturation with hydrogen sulphide.....	2	97	3
Acidulation	65	90	75
Electrolysis for 24 hours.....	100	100	100
Agitation for 15 minutes with zinc dust..	25	60	3
Agitation with zinc dust and filter-pressing	94	97	4

Six Months' Experience with Similar Solutions, Using Zinc Dust and Filter-Pressing.

KCN. averaging 0.04 per cent...	98 10 99.	Over 96	2 to 4
KCN. from .08 to 0.1 per cent...	98 to 99.	Over 96	0.5 to 1

These figures bring out the fact that silver is, as a rule, easier to precipitate than gold, just as it is slower to dissolve in cyanide solutions. The author concludes that it impossible to draw any general comparison between the merits of the different zinc and electrolytic methods of precipitation, but gives the following figures as based on practical results, with material of moderately low value, all being calculated to a standard, or 100 tons solution precipitated per day: Electrolysis; precipitating tank of 1,200 cubic feet capacity, say a box 10 by 24 feet, having about 3000 square feet each of anode and cathode surface. This would require five or six horse-power for electrolysis, in addition to the power for pumping. The actual precipitation obtained at two plants averages very close to 90 per cent of the value in solution. Zinc shavings, 100 cubic feet of capacity for the zinc, or about 175 gross cubic feet of zinc boxes, say, two boxes 2 by 2 feet by 9 inches by 16 feet, using 25 to 30 pounds of zinc per day, the only power required being for pumping the solution and turning the zinc. The actual precipitation obtained may be taken at 90 per cent under favorable circumstances. Zinc dust; one filter press with 16 frames, about 2 feet square, working not over 15 or 16 hours per day, would require about 2 horse-power during that time (neglecting any additional friction in pumps) in excess of the power required for pumping solution from pumps in the last case. Some power is also needed for stirring or agitating solution when adding zinc, but this is only for a few minutes at a time. The percentage of precious metals precipitated at two plants ranges from 95 to over 98 per cent, from 20 to 30 pounds zinc dust being used per 100 tons. Owing to the greater cost of the machinery required for the electrolytic and zinc-dust processes, it is evident that the zinc-shavings system is by far the best adapted to all small or temporary plants; but with installations intended to treat 100 tons or more per day, or likely to be in use for several years, the merits of the other systems should be considered.

De-tinning of Scrap.—Dr. H. Mennicke continues in the March number of the *Elektrochemische Zeitschrift* his study of the advances in this art since 1902. This last instalment treats of the non-electrical methods. Bergmann, in a Swedish patent (No. 14,156 of June 6, 1901), treats the scrap in an iron vessel with caustic soda solution, using suspended cupric oxide as a depolarizer. The supric oxide forms voltaic couples with the tin, and the latter goes into solution as sodium stannate. The solution is filtered, concentrated and precipitated by a stream of carbon dioxide. The precipitate is filtered out, dissolved in acid, and the tin precipitated electrolytically. Dr. Mennicke maintains that it would be cheaper to treat the stannate solution direct electrolytically; it appears to the reviewer that since precipitation by carbon dioxide is a cheap

process, that it might be equally cheap to precipitate, filter, and then reduce the tin oxide by carbon in a shaft furnace. In any event, either of these suggested variations would be cheaper than the original proposition of Bergmann.

Th. Twynam, of Leeds, England, has devised a method which appears to Dr. Mennicke as being very simple, cheap and direct. The scrap is dipped into a thick mush of concentrated salt solution and powdered coke, taken out at once, and then let stand some time in the air. The tin is oxidized to tin oxide and falls off the scrap, or is washed off with the unchanged salt, caustic and coke, leaving the iron as clean black iron. The wash water is filtered, thus recovering part of the tin as oxide and basic chloride, with coke powder; which mixture, after drying, is reduced in a reverberatory furnace. Some tin goes into solution as stannate, and accumulates until in sufficient amount to be electrolytically precipitated out. Twynam speaks of the oxidation in the air being complete in an hour, but investigations of Mennicke have shown that a longer time is necessary; also that iron rust on the scrap will be mixed with the tin oxide obtained, thus showing that the process will require large working space for the heaps exposed to the weather, and that only clean, bright tin scrap can be advantageously treated. The treatment of the subject by Dr. Mennicke is to be continued in subsequent issues.

METALLURGY.

Dry Air in Blast Furnaces.—O. Boudouard rushes into the breach, in the February number of the *Revue de Metallurgie* with a new theory to explain the importance of drying the blast. He has made experiments with carbonic oxide on iron oxides, and finds that if moisture is present with the reducing gas that reduction is slightly less active at temperatures below 1000° C., and thence concludes that the removal of this moisture accounts for the greater economy by increasing the reducing power of the gas. The weak point of these views is that the differences found were not large or very clearly marked, and that, even if they are true experimentally, there is no doubt that they do not apply to the case under discussion, because the moisture of the blast is decomposed to hydrogen (and carbonous oxide) at the tuyeres, and it is the action of a mixture of hydrogen with carbonic oxide on the reduction of the ores which M. Boudouard should have studied, instead of the influence of moisture.

Of much greater value, and, indeed, worthy of attention, is an address on the same subject made by the well-known German chemical engineer Dr. C. von Linde, before the *Verein Deutscher Eisenhüttenleute* at the recent yearly meeting in Düsseldorf, on December 4, as reported in *Stahl und Eisen* for January 1. Dr. Linde starts out very happily by remarking that "the 'Eismann' has come to the help of the 'Eisen hüttenmann.'" His paper discussed the cost of cooling the blast. To cool one cubic meter of air 27° C. absorbs about 8 calories, and to condense 9 grams of moisture 6 calories, making a total refrigerating requirement of 14 calories. Since a horse-power-hour can exert a refrigerating effect of 3600 calories, one horse-power should refrigerate 250 cubic meters of air, 27° C. It is interesting to compare this with the power needed to compress the blast; this requires on an average one horse-power-hour for every 25 cubic meters compressed, showing that the refrigerating requires about one-tenth of the power needed by the compressing engine. A plant to cool 1000 cubic meters of air per minute requiring about 240 horse-power, would cost, approximately, $50,000. Extensive experience with air refrigerating plants has shown that such cooling plants easily work twenty years without great deterioration, so that a yearly charge of 5 per cent for deterioration, or $2,500 is quite sufficient; interest on average capital at 5 per cent would be $1,250; labor can be put at $2,000, and general expenses, including repairs, $2,000, making the total yearly cost of the operation $7,750 ($21.11 daily, or less than $0.10 per ton of iron made). An important point must, however, not be overlooked. Six out of the 14 calories required for cooling the air is absorbed as latent heat in the ice formed, and is therefore in such a form as to be partially recoverable; that is, part of it can be utilized for cooling down the incoming air. This utilization may not be perfect, but if only 20 per cent of it is thus utilized, the heat to be absorbed per cubic meter of air cooled is reduced 1.2 calories out of 14, or by 9 per cent, making the cost of the plant necessary only some $45,000, in place of $50,000, and reducing expenses in about the same proportion. The figures above given are not theoretical data, or mere estimates, but rest on many years' practical experience with refrigerating plants.

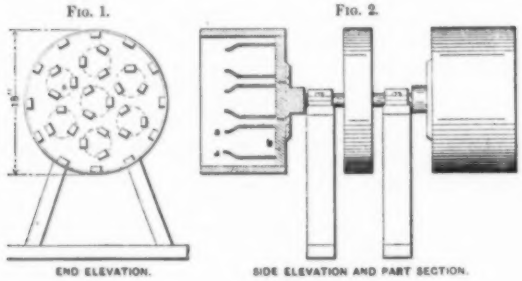
In the discussion of Dr. Linde's paper, Dr. Weiskopf, of Hanover, referred to the results obtained by Mr. Gayley (increased output of furnace, 24 per cent, decreased consumption of coke 20 per cent), and after remarking that these results were totally unexplainable by the mere saving of the heat necessary to decompose the ordinary moisture of the blast, advanced the suggestion (somewhat similar to Boudouard's) that the absence of hydrogen in the furnace gases must in some mysterious way be the cause of the improvements noted, but gives no satisfactory reasons as to the why or wherefore of this influence. If the equations of reduction of iron oxide by carbonous oxide and hydrogen are, in fact, carefully studied, it will be found that the presence of extra carbonous oxide and hydrogen coming from the decomposition of moisture should *facilitate* reduction, and therefore their removal or absence should make the reduction poorer. The argument that the heat required to decompose the moisture of the blast is regained in the upper part of the furnace by the reoxidation of the hydrogen, and that therefore the removal of the moisture does not assist the furnace by reason of the avoidance of heat absorption in decomposing it, is a statement hardly needing refutation. Everyone who knows how a blast furnace works knows that, like a human being, it works best with warm feet and a cool head—hot below and cool above.

Herr Direktor Haedicke, of Siegen, mixed up the matter still worse. He maintained that the question was one of the physical condition of the moisture in the air; that such cool moisture was really liquid water in suspension; that it was not decomposable by glowing carbon like real high temperature steam, and that the only action of the blast furnace on such cold moisture was to truly vaporize it. Since the vaporization of the ordinary amount of moisture in the air would require but a very small amount of heat, the conclusion was evident that, if Mr. Gayley's statements were reliable, the removal of the moisture from the blast was not the real cause of the improvement. We are sorry that *Stahl und Eisen* was complaisant enough to print such gibberish.

Engineer Dr. Lürman, of Berlin, made the most serious attempt to cut this siderological "Gordian knot." In his contribution to the discussion he made the following points: (1) The volumes of air blown into the furnace without dried blast and with dried blast do not correspond with the dimensions and rate of running of the engine given by Mr. Gayley, and are inconsistent with the amount of coke burned per day in the furnace in each case. As to the first statement, it is true that there is only a rough correspondence between the piston displacement and the volumes given by Mr. Gayley, but Dr. Lürman has forgotten that the air blown into the furnace is not equal to the piston displacement, and that Mr. Gayley estimated an average net deliverey of 90 per cent. This was really the only thing Mr. Gayley could do, but he failed to state in so many words that he had done so; when this fact is recognized, the apparent inconsistency disappears. On the next count, Dr. Lürman is again wrong, for he forgets that the same proportion of carbon need not always be burnt at the tuyeres; that varying proportions of it may be consumed above the tuyeres in direct reduction, and that the air received by the furnace in the two cases is not necessarily proportional to the amount of coke put into the furnace in each case. In

reality, a much smaller proportion of the coke is burned at the tuyeres in the case of dried blast than with moist blast, and Dr. Lüman's criticism loses its point because of failure to notice that fact. (2) The decomposition of the moisture blown in could only absorb 3.64 per cent of the heating power of the coke burned, and the actual result obtained by Mr. Gayley being a saving of 19.5 per cent, the removal of the moisture cannot account for the larger part of the saving. The blast was, however, warmer in the case of dried blast, but this can only account for a saving of 8.5 per cent of the calorific power of the coke. The two together are therefore unable to account for the saving, and Dr. Lürman's final effort at a solution is the opinion that the furnace was receiving too much coke to start with; that it was, so to speak, overfed with coke, and, like an overfed human being, it improved in working capacity and economized at the same time by being put on a more restricted diet. *Next!*

Chlorination and Bromination of Gold.—An interesting paper, presented before the American Institute of Mining Engineers by H. O. Hofman and M. G. Magnuson, is published in the March issue of the *Bi-Monthly Bulletin* of the Institute. The aim of the research was to find the dissolving power of chlorine-water and of bromine-water upon gold and upon a series of alloys of gold and silver, the operations being carried out in revolving vessels. The dissolving tests were made in pint fruit jars of glass, 3 inches in diameter and 6 inches high, the covers being held in place by screw-clamps, and the joints made tight by rubber gaskets. The jars were rotated in the Richards revolving apparatus shown in Figs. 1 and 2. This is seen to consist of a horizontal shaft with pulley, having at either end a cylindrical box holding seven jars. A box has a wooden bottom, twelve staves connected by a stout wire, and sides of 2.5-pound lead. A jar is held loosely in a horizontal position by three sheet-steel springs screwed to the wooden bottom. A circular felt pad, *b*, tacked down between three springs protects the bottle against jarring. The barrel makes 4.3 revolutions per minute. The results are given in tables and diagrams. One diagram is reproduced in Fig. 3, the constant for each curve being the quantity of active reagent in 150 c. c. water; the percentage of extraction is given as ordinate, and the ratios of gold and silver in the alloy as



FIGS. 1 AND 2.—REVOLVING APPARATUS FOR CHLORINATION.

abscissas. A supersaturated solution of chlorine in water acts more strongly than one that is merely saturated; a supersaturated solution can extract a satisfactory percentage of gold from a gold-silver alloy containing as much as 20 per cent of silver, while with the decrease of chlorine flow a certain amount (2.1 g.) and the increase of silver above 10 per cent, the extraction of gold falls off quickly. Bromine is also an efficient solvent for gold, giving extractions of 99.8, 98.2, 96.6, 93.2 and 92.2 per cent, with solutions of 8.97, 5.98, 4.48, 2.90 and 2.60 g. of bromine in 150 c. c. of water; when the bromine present sinks to 2.1 g. the yield in gold falls quickly to 34.2 per cent, and then diminishes more gradually. With the concentrated solutions (2.8 g. of Cl equivalent to 6.0 g. of Br.), chlorine is a slightly stronger solvent than bromine. For concentrations below 1.58 gram chlorine (equivalent to 3.4 gram of bromine) bromine is a better solvent than chlorine. The

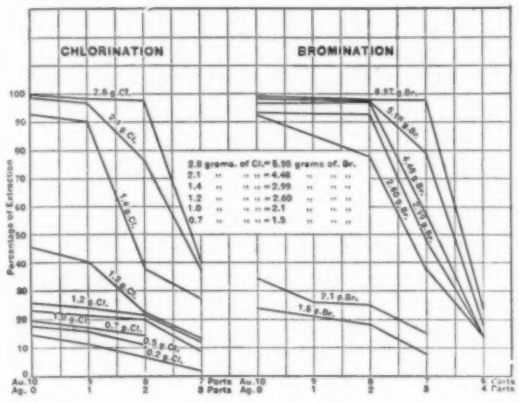

CHLORINATION
BROMINATION
Percentage of Extraction
2.8 g Cl.
2.1 g Cl.
1.4 g Cl.
1.2 g Cl.
1.0 g Cl.
0.7 g Cl.
0.5 g Cl.
0.2 g Cl.
8.97 g Br.
5.98 g Br.
4.48 g Br.
2.60 g Br.
2.25 g Br.
2.1 g Br.
1.6 g Br.
2.8 grams of Cl = 5.90 grams of Br.
2.1 " " = 4.48 " "
1.4 " " = 2.99 " "
1.2 " " = 2.60 " "
1.0 " " = 2.1 " "
0.7 " " = 1.5 " "
Au. 10 Ag. 0
1 Parts Au. 10 8 Parts Ag. 9
4 Parts

FIG. 3.—RESULTS OF CHLORINATION AND BROMINATION TESTS.

curves in Fig. 3 bring out forcibly the result which the per cents of large proportions of silver may have upon the extraction of gold.

On account of limitations of space a number of abstracts had to be reserved for our next issue.

BOOK REVIEWS.

Electricity in Every-Day Life. By Edwin J. Houston, Ph. D. New York: Collier's Weekly. Three volumes, 584, 566 and 610 pages, respectively. Illustrated. Price, $4.50.

The contents of these books are best indicated by the headings of the different sections; viz., Electricity of High Electromotive Force (13 chapters), Magnetism (8 chapters), The Voltaic Cell (4 chapters), Other Sources of Electricity (4 chapters), Production of Electricity from Magnetism (8 chapters), Electric Lighting (21 chapters), Electric Power (10 chapters), Electrochemistry (5 chapters), The Telephone (6 chapters), The Telegraph (12 chapters), Annunciators and Alarms (3 chapters), Heating (4 chapters), Electro-Therapeutics (3 chapters).

Under each heading, the successive chapters take up first the early history, with considerable reference to the personality of the inventors, and then follow descriptions of the development of the subject, right up to date. The reviewer was unable to think of any recent development in any of these lines which he did not find indexed and described. The completeness of the work is therefore very meritorious, considering the great range of subjects treated.

Two or three marginal annotations on each page facilitate reference to the sub-divisions of the topics treated, and unusually complete indexes add still to the value of the work for reference. The type is large and clear, the paper, however, poor. It is a pity that the publishers could not have afforded a quality of paper good enough to prevent print showing through so plainly. The binding is neat and attractive; the numbers of the volumes should have been printed on the backs more conspicuously.

Aside from the paper, the work is in every respect the opposite of the ordinary "cheap" book. It is logically arranged, comprehensive and right up-to-date, and written by an electrician whose name is almost a household word, whose skill as a teacher has been derived from a twenty-five years' professorship of physics, and who has written these books in his

clearest and happiest style. No books could be better suited for giving to school boys and girls in their teens, to the apprentice or artisan, to the business man or farmer, to the seamstress or the clerk, the minister or lawyer, a clear and reliable account of "Electricity in Every-Day Life." Neither will the scientific man find it beneath his attention, for the chronological arrangement and complete index will make the work valuable for reference.

Plant of the Shawinigan Water & Power Company.

The power development of this Canadian company is located at Shawinigan Falls in the Province of Quebec, on the St. Maurice River, about 85 miles from Montreal.

The company has just finished the installation of the largest water-wheel in the world, which was built by the I. P. Morris Co., of Philadelphia. This monster turbine is of 10,500 hp. capacity, is 30 feet from base to top, is 22 feet wide over all and weighs 182 tons. There is direct connected to this turbine a Westinghouse generator of 10,000 hp., and with this installation, the company has now a power house and machinery with a capacity of 25,000 hp.

In addition to this, 15,000 hp. is sold in the form of hydraulic power to the Northern Aluminum Co., and the Belgo Pulp & Paper Co. Other users of power at Shawinigan Falls are the Shawinigan Carbide Co., manufacturing calcium carbide; the Electro Manganese Co., manufacturing ferro-manganese, and lighting companies.

In addition to selling power at Shawinigan Falls, the company furnishes power in the city of Montreal for street railway and industrial purposes, transmitting at 50,000 volts over an equipment of two transmission lines parallel to each other and comprising the longest transmission line of such high voltage in the world.

At Montreal, the company has a terminal station where the current is stepped down and the frequency changed. In this station, during the month of March, there was put into successful operation the largest frequency changer ever built. It was manufactured by the Bullock Electric Manufacturing Co., of Cincinnati. The current from Shawinigan Falls is transmitted at 30 cycles, and is changed to 60 cycles for the use of the city lighting and power mains. The gigantic frequency changer consists of a synchronous motor directly connected to a generator and a starting motor all on the same shaft and mounted on the same base. A few figures will show the enormous size of this machine. The total length of the frequency changer is 30 feet and the motor and the generator are each 15 feet high, the total weight is 250 tons. The set, composed of a 7500-hp. motor driving the 5300-kw. generator, approximates 14,600 hp. There were already in the station five smaller 800-kw. frequency changers, so that the capacity of this sub-station is now doubled. The company is now delivering in Montreal a total of 9000 hp., and is making arrangements to increase this output to satisfy demands for additional power already made.

With its cheap power and good railway facilities, which are this year being added to by new lines of railroad, Shawinigan Falls possess advantages which offer large attractions to companies now located there, and has a great future before it as a manufacturing town.

Mechanical Desulphurizing Furnace.

In the following we give a description of the O'Brien mechanical roasting furnace which was worked out by Mr. A. P. O'Brien and installed at his works, the Richmond Guano Company, Richmond, Va., about four years ago. Within the past year the American Coke & Gas Construction Company has secured the rights to this roaster and has thoroughly perfected it mechanically. Some 25 installations made during the past few months have given such fully satisfactory results that the following description should be of interest to engineers and managers of metallurgical, chemical and fertilizer works.

The furnace is built in two distinct types:

Type A.—Plain furnace for desulphurizing metallic bisulphides, iron and copper pyrites, fines and concentrates, etc.

Type B.—Muffled furnace for desulphurizing zinc blende, pyrrhotite refractory sulphides, etc.

These furnaces embody a number of distinctive and valuable features which, for the most part, will be noted by reference to the accompanying illustration of the type "A" furnace.

The furnace consists of an iron shell enclosing and supporting brick shelves and lining. This shell is supported by channel and I-beam posts resting on a circular foundation wall. Two of these posts are connected by horizontal I-beams, upon which in the center is a ball-thrust-bearing, which supports the tapering, tubular air-cooled shaft. The I-beams supporting the shaft rest on set screws which provide for the adjustment and alignment of the shaft. This shaft may be removed while the furnace is under fire, and a new shaft may be used or the old one repaired without letting the fire go out. The air-cooled rakes are inserted in removable sockets in the shaft and cannot rise or turn; they keep a true and even bed on each shelf, being locked in place by means of a slot and key; they may readily be removed or replaced. The teeth of the rakes are in proportion to move the ore at a uniform speed from the center to the circumference of the shelves, and vice versa. The furnace is provided with ore feed hopper, and a mechanically-driven screw feed; in the brick shelves are provided a sufficient number of openings for the dropping of the ore from the upper to the lower shelves; tubular outlets discharge the cinder from the bottom of the furnace; these latter are fitted with closing slides so that the air drawn into the furnace may be regulated to afford proper combustion; a further regulation of air is afforded by adjusting slides in the doors opening to each shelf.

The furnace is provided with two sets of doors opening into each compartment; one set is placed diametrically opposite the other so that repairs may easily be made. An iron ladder designed for water cooling, if desired, is supported by the shell and runs alongside each set of doors, and the doors are made to lock when shut or open, so that the examination and working of the furnace is extremely simple. The furnace shaft and rakes are driven by pinion and rack; the meshing of the rack and pinion teeth is so governed that any possible obstruction within the furnace will cause the teeth of the rack to jump out of mesh, and the loud clinking noise will attract the operator's attention, who may immediately stop the furance by the throw of a lever and so prevent damage.

The alternate brick shelves are provided with luting rings, and the shaft with lute covers which prevent the escape of gas through any but the desired openings; this is also true of the furnace top plate. An elbow provided with clean-out and shut-off damper serves as a gas off-take; both the gas off-take and ore-feed are set to the furnace with gas-tight connections.

The furnace is mechanically driven, and any number of them may be run in series as is shown in the illustration of the furnace room arrangement; any one or more so run may be independently cut out by the throwing of a lever to a position which raises the rack teeth out of mesh with the pinion; this is readily done owing to the flexibility of the rack plate. The power required for the mechanical operations of one furnace equals approximately ⅛ of a horse-power.

A few of the distinct advantages claimed for this furnace are:

The arms are put in and taken out horizontally and without raising.

Consequently the shelves are closer together, and the radiant heat is better utilized, securing a more complete roast and greater efficiency.

Further, for the same reason, there is room for an additional shelf without increasing the height of the furnace.

For the above reasons the capacity of this furnace is increased at least 20 per cent. over any other of the same size on the market.

Far less power is required than for any other furnace of equal capacity.

The feed is automatic, positive and easily regulated from the floor, and is equally efficient for all grades of ore. This feed will work so accurately that the operator will know exactly the amount of ore being fed.

Repairs are much less than on any similar type of furnace. The rabble arms, which are the wearing part, are shorter and lighter than in any other furnace; owing to this and their air-cooling system they last longer and cost less to replace

The air-cooling system is positive; cool air enters at the bottom of the tapering tubular cast-iron shaft and must pass through every division of the shaft and rabble arms before it escapes from the shaft top.

No stack is required, nor other artificial means of creating a draft through the central shaft.

The central shaft can be withdrawn and replaced in a short time without cooling or tearing apart the furnace.

The driving mechanism is light, simple and near the periphery of the furnace where it can easily be reached for oiling and repairing, instead of being, as usual, at the center of the furnace where it is almost inaccessible.

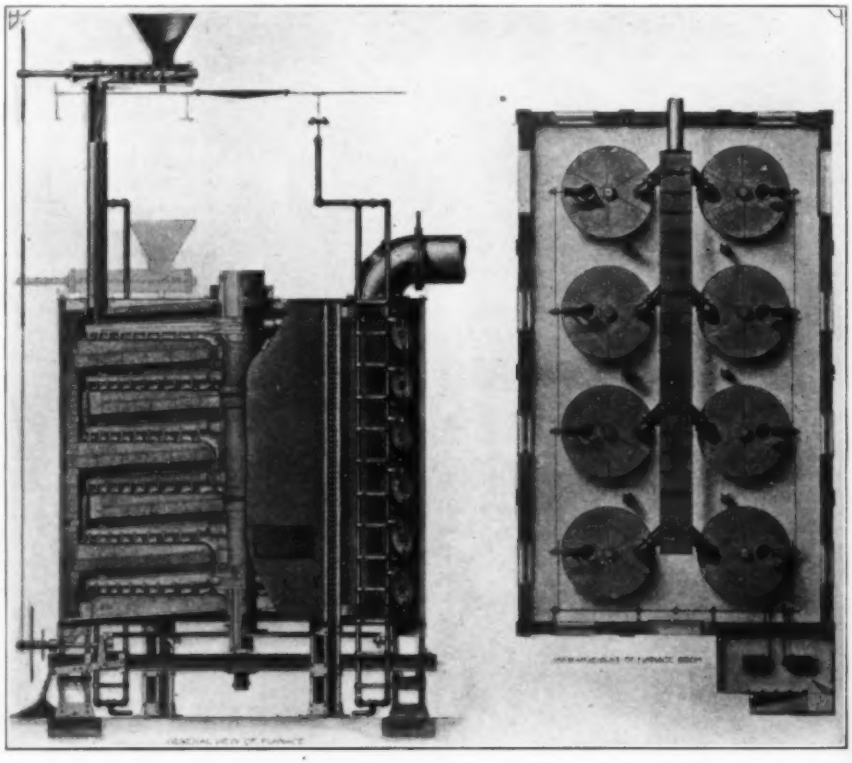
There are many other advantages which must be seen in operation to be appreciated.

The muffled furnace (type B) possesses all the advantages of the plain furnace, and closely follows the same in design, except that it is provided with combustion chambers for supplying extraneous heat for the satisfactory desulphurization of refractory ores. For this purpose chambers are built under each of the three lower roasting shelves to receive the fuel required to keep the heat of these shelves at the necessary temperature; the chambers are furnished with air inlet which may be so regulated that the complete combustion of the fuel supplied is assured therein; there are provided a sufficient number of flues, running up within the brick lining of the furnace, to carry off the products of combustion; otherwise the combustion chambers are air tight, and no escape of their products into the roasting chambers, or gases from roasting chambers to combustion chambers, is possible. In order to prevent undue radiation of heat an intermediate lining of non-conducting material is set between brick wall and steel shell.

An iron flue and stack connected to the flues from the combustion chambers lead the waste products off to discharge above the furnace. The additional heat required for desulphurizing the refractory ores can be applied either by natural or producer gas, fuel oil, pulverized fuel, or from an outside combustion furnace as may be most economical in any given locality.

The extreme mechanical simplicity and compactness of these furnaces, their great ease of operation and thorough regulation of all conditions affecting the roast, their construction, which minimizes the necessity of repairs, and the facility with which any necessary repairs may be made to any parts greatly commends them.

The type "A" furnace which is designed for roasting ores high in sulphur content requires no fuel on ores carrying from 30 to 50 per cent. of sulphur; such ores can be roasted down to a "dead" cinder by their own heat alone. It is adapted particularly for chemical and fertilizer works where the



MECHANICAL DESULPHURIZING FURNACE.

fumes from the ores are to be converted into sulphuric acid.

By passing these fumes or gases through an ordinary dust collector, a comparatively clean gas without material reduction of temperature is afforded, thus insuring the efficiency of the Glover tower and purity of the Glover tower acid; and by the use of especially designed cleaning system and absolutely pure SO_2 gas may be secured.

The type "B" furnace, designed for roasting refractory ores, is especially adaptable for the demands of metallurgical works, affording a large output of ore at a "dead" roast, or any required degree of desulphurization and securing a complete saving of flue dust and fume losses.

A number of these furnaces have been installed in works of varied character in this country and abroad and are exceedingly satisfactory in every instance. Further particulars regarding these furnaces may be obtained by addressing the American Coke and Gas Construction Company, 17 Battery Place, New York City, or their engineering offices, at Camden,

New Jersey, which company has secured the sole right to the manufacture and sale of these furnaces in all countries, installing them under guarantee.

Bijur Storage Battery.

The first storage battery was devised by Plante, who formed two sheets of lead in sulphuric acid by a long and tedious purely electrochemical process. Faure and Brush avoided this long treatment by mechanically appplying the active mass to the electrodes. Then began an enormous activity of inventors who essentially worked in three different directions. One class worked along the lines of Plante, but endeavored to reduce the time of formation by the use of oxidizing electrolytes instead of, or in addition to, sulphuric acid, or by a purely chemical method of formation. A second class of inventors worked along the lines of Faure, but they were hindered in this country by the Brush patents, which only expired in 1903. A third class tried to develop an accumulator without lead, using a new electrochemical reaction; examples are the old Waddell-Entz and the new Edison batteries.

In view of this development it is certainly interesting to note that the latest type of commercial storage battery which, having been most carefully worked out, is now being placed on the market and manufactured on a large scale, is of the old Plante type, although a new (secret electrolytic) process of formation is used in its manufacture. In various respects, the Bijur battery differs radically in design, construction and manufacture from forms hitherto known in the storage battery art, yet its most conspicuous feature is a certain sound conservatism—the fact that its novel design is directly a consequence of combining old, well-known, sound engineering principles with results derived from the most reliable modern theoretical investigations on the reactions in the lead cell.

The battery is the result of several years' work on the part of Mr. Joseph Bijur, of New York City. With the collaboration of Dr. J. S. C. Wells, of Columbia University, in the earlier stages of the work, Mr. Bijur set out to produce a battery plate according to an ideal design which should be both mechanically and chemically perfect.

To get a mechanically perfect plate it is all important to provide a rigid structure, free from tendency to distortion and with the active material applied in such a way that it cannot be displaced. The ideal construction of a plate fulfilling this requirement is to make it up of small, finely sub-divided structures, each free to expand unrestrainedly, and firmly welded to a strong supporting and conducting grid. This construction has been adopted by Mr. Bijur. For this purpose a large amount of experimental work had to be done. To reduce the cost, automatic machinery had to be devised. But, above all, by no method of metal working then existing was it possible to commercially weld together two elements, of which one was a heavy, solid form and the other of very fine, thin parts. It was, therefore, necessary to devise a new method of metal welding which, after much patient work, in the face of seemingly insuperable difficulties, was successfully accomplished, and for the carrying out of which, on a commercial scale, an entire line of machinery was constructed on original lines.

But before describing the details of the construction we must refer to the chemistry of the subject which determines, in many respects, the satisfactory behavior of an accumulator.

The reaction during discharge is

$$PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O.$$

The reaction during charge is the reverse. The e. m. f. of the cell depends on the concentration of the acid and decreases with it. Moreover, the concentration of the acid in the pores of the plates is the determining factor. Now, from the above equation it will be seen that acid is consumed during discharge, *i. e.*, the solution becomes more dilute, the voltage decreases. If the discharge is made at a high rate, the solution in the pores of the plates becomes more dilute than outside, because diffusion cannot bring fresh solution quickly enough into the pores. For this reason there is a further drop of voltage. Thus, the possibility of free diffusion does not allow the voltage to drop so quickly during a high-rate discharge. On the other hand, with free diffusion the voltage does not rise so quickly during a quick discharge. Hence, diffusion is a most important factor in determining the efficiency of a lead cell.

It is also of great importance with the respect to the phenomenon called sulphatation or sulphatization. While the formation of sulphate during discharge is the natural thing and the very reaction which gives the electrical energy, yet over-production of sulphate, and especially formation of sulphate crystals, is one of the worst diseases of a lead cell. According to one of the most reasonable explanations of this phenomenon, it is in intimate connection with the solubility of lead sulphate[1]; this seems to have a minimum in a 14 to 16 per cent H_2SO_4 solution. If the concentration becomes very much higher, or much lower, the solubility, and with it the liability, of sulphatation increases. For this reason it is so detrimental for an accumulator to stand for a long while in an acid which is too strong or too weak. Here, again, free diffusion is beneficial, since it prevents the concentration in the pores from becoming excessively high or low. These brief remarks do not approximately exhaust the subject, but they must suffice to indicate the importance of free diffusion. It is in this respect that the design of the Bijur battery is especially remarkable; his large surface of active mass is so arranged that the outside solution has always free access to the pores of the active mass.

As is clearly shown in the adjoining illustrations, the Bijur plates are composed of multiples of pure lead structures in the shape of gratings or "grills." These are welded to, and in one piece with, a stiff frame made of lead and antimony only. The weld goes clear through the plates and is produced without the use of tin, solder flux or any extraneous material whatsoever. The frame merges into the grill without joint. At each end of the grill a space is provided for its elongation by expansion, and provision is made for expansion sidewise. The result is a plate having the stiffness, strength and inoxidizable support of the alloy grid, rigidly held active parts, yet complete provision for their expansion without the setting up of any strains that could produce buckling.

The grills are composed of a multitude of thin partitions, open through from face to face. When in the untreated metallic state these grills are very open structures, having a large number of component ribbons running in the vertical direction, supported by heavier cross members running horizontally, which serve as conductors and give lateral stiffness. During the formation process part of the metallic lead is converted into oxide, which, by reason of the large increase in volume, nearly fills the openings. The ribbons on the positive elements have a large amount of metal left as a reserve for the oxidation which is attendant on the normal action of every storage battery. The vertical direction of the ribbons aids diffusion, since during discharge the dilute solution from the pores of the plates rises upwards, while fresh solution enters the pores.

When the oxide is formed in the rectangular cells it assumes a slightly elliptical shape, which, expanding into the rectangular containing space, produces a locking in that is so positive that nothing short of destruction of the plate can dislodge it. At the same time, even when the oxidization is carried to the point of apparently completely filling the cells, the tendency of the ellipse to grow larger along both its axes, insures the presence of a minute slot through the center of the oxide mass, which allows the flow of electrolyte to take place freely through it. The resultant oxidized plate, therefore, is

[1] See, for instance, Dolezalek, Theory of Lead Accumulator. American edition, page 140.

rigid, the grills are firmly held, they expand without producing strains, each particle of oxide is firmly pressed against the lead from which it is grown, and the entire plate is open through and through to circulation and diffusion of the electrolyte.

Owing to the character of the design and the structure of the oxide formed, the plates possess several features hitherto unattained in battery practice. "Buckling" cannot take place, and so far repeated attempts to intentionally produce distortion have failed. Also, since the perfect diffusion through the plate prevents too high or too low acid concentration in the pores, deleterious sulphation does not take place, even when an effort is made to produce it.

One of the important advantages gained by this form of design is that in a plate of given dimensions, 20 per cent greater capacity can be obtained with about 10 per cent more reserve lead than in any form of plate hitherto constructed. The fine sub-division of the oxide into small masses, combined with the fact that the surfaces of the plates are composed of ribbons on edge precludes the possibility of blistering or shrinkage that is liable to occur when plates contain oxides in large masses.

The makers claim that owing to the rapid acid diffusion full charge may be given the batteries at a voltage of 2.4 to 2.5 volts instead of 2.7 volts per cell, as is usually required. This low-charging voltage results in increase of efficiency, and reduces the size of boosters required to charge.

The structure of the plate forms a conducting network to all parts, insuring equality of action all over its surface, and this, together with the facility for escape of gas without dislodging active material, favors the ability to stand very high rates of charge and overcharge without marked deterioration.

In short, since storage battery plates can be calculated out scientifically and then constructed in exact accordance with the design, the series of developments and inventions of Mr. Bijur places the manufacture of storage batteries on the same basis as that of dynamo-electric machinery. These processes permit of any suitable forms of active parts and supporting

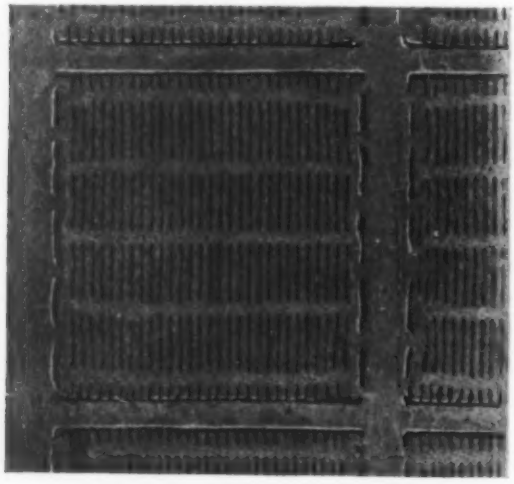


FIG. 1.—SECTION OF FORMED BIJUR PLATE.

frame-work being united into one integral structure at a low cost of production and without the introduction of any foreign substances.

The General Storage Battery Co., which is now putting elements of this type on the market under the name of the Bijur "High Duty" battery, has recently equipped a factory at Boonton, N. J., with special automatic machinery for the cheap and rapid production of this battery, where, by reason of an abundant and cheap hydraulic power and the automatic machinery used, storage batteries of the highest grade can be produced, it is claimed, for a lower cost per kilowatt-hour capacity than is possible anywhere else in the country.

The company has also developed a new and complete line of automatic regulating boosters and cell switches, and other auxiliary apparatus for all classes of central station work and

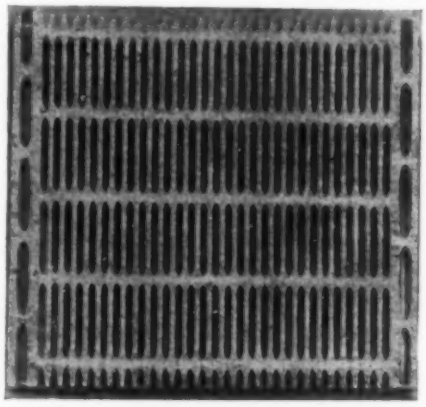


FIG. 2.—UNFORMED BIJUR GRILL.

power plants, descriptions of which will appear later. It may be said that all of these devices differ as radically from the present known types as does the Bijur "High-Duty" battery from the conventional storage battery electrodes, and the improvement in methods and degree of regulation represents a marked advance in storage battery engineering.

A Preventive for Lead and Mercury Poisoning.

It has long been recognized as the result of extended researches that lead poisoning is due to the introduction of the poison from the hand into the mouth, while eating, and that this process goes on even if the workingmen, before taking their meals, have taken great care to clean their hands thoroughly with ordinary soap. The reason is that lead soaps are thereby formed which adhere to the skin firmly, and are not less poisonous than the original lead compounds. The lead is then introduced through the mouth into the system.

The only remedy is evident. It is to use such a soap that a harmless, non-poisonous compound is formed by the soap on the hands. This effect is claimed for the "Akremnine" soap, by the application of which non-poisonous lead sulphide is produced. The soap is stated to have the same effect in preventing mercury and copper poisoning. The Akremnine soap has been used for several years in Europe, and, according to published statements of Dr. Blum, Dr. Umbash, Dr. Merckens and others, has proven completely satisfactory, combining the advantages of ordinary soap with those of a disinfectant.

The Akremnine soap is now being introduced in this country by Mr. Felix Hamburger, 90 William Street, New York City.

Welding of Broken Bosses on Rolls by Thermit.

When, in the beginning of the war in the Far East, the Russian battleships were disabled by the Japanese, considerable surprise was expressed at the remarkable quickness with which the Russians were able to make repairs. This was in most cases due to the application of thermit, which was carried in considerable quantities on every battleship. The Japanese quickly learned the lesson, and are now paying due attention to the possibilities of thermit.

In this country, the Goldschmidt Thermit Co., of New York City, commences to introduce thermit very extensively for more peaceful purposes, in making repairs of broken castings

in railroad shops, steel plants, rolling mills, etc. The general possibilities of thermit for repairs were fully discussed by Dr. Hans Goldschmidt himself in our Vol. I, page 527 (see also Vol. II, page 404). In the following some more recent developments shall be dealt with.

In railroad shops the most important, although most difficult, problem is the welding of broken locomotive frames. By means of thermit it is possible to perform the whole repair in the round-house within fifteen hours (against two weeks by the older method). There is no transference to the machine shop, no dismantling of the locomotive. However, this special problem requires considerable experience in the handling of thermit; nevertheless, one railroad company has already repaired more than forty locomotive frames with thermit with perfect success.

For general repair work in machine shops thermit is now very largely used, and recently some very interesting repairs of broken cast iron were performed. In one case it was the part of a machine used to press wheels on axles; this part bears directly over the hub of the wheel during the passage of the axle under a pressure of 60 tons per inch. On account of this high pressure the part had broken into two pieces, but was repaired by thermit with perfect success by the engineer of the company itself. This indicates considerable skill on his part, but it also indicates the possibilities which the application of thermit offers to every iron and steel plant.

Of special interest for rolling mills is the use of thermit for welding broken bosses on rolls. Hitherto it has been the practice to make the broken boss red-hot by means of a basket of coke placed upon it, and then pour liquid iron or steel on it. This is rendered unnecessary by the application of thermit, which does the work more simply, cheaply and effectually, as will be described.

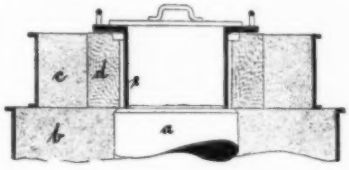


FIG. 1.—THERMIT WELDING OF BROKEN ROLL.

Thermit ignited on a cold surface deposits on it a layer of corundum (aluminium oxide) slag, which adheres firmly. To avoid this, a thin layer of cast iron or steel is poured onto the welding surface before thermit is placed on it, and to avoid the adhesion of corundum at the sides, a concentric iron ring is so fixed in the mold that it can be withdrawn after ignition of the thermit, as shown in Fig. 1. In this illustration *a* represents the roll, *b* and *c* dirt, *d* the mold. The method of procedure is as follows. The roll is firmly fixed in such a position that the welding surface lies horizontally. After placing the first mold, which has a diameter exceeding 2½ inches that of the boss to be welded, a cast-iron ring, with two lugs attached for lifting, is placed in the mold. This ring *c* is ½ inch thick, and stands off about ½ inch from the inner wall of the mold. It is constructed so as to overlap like a flange the upper part of the lower mold box without touching its edge. The ring must be well covered with graphite and the inner surface well smeared with clay and dried. It must tightly fit onto the roll, and, where necessary, spaces must be stopped with clay. The clay must not exude onto the inner face, as moisture on the welding surface is bad.

The flange-like rim of the ring is made to overlap the edge of the mold and protect it from any drops of liquid iron which may splash up during the reaction and pouring of the metal.

About 30 pounds of thermit are required to the superficial foot of cast-iron surface. This quantity will soften the metal to the depth of about 2 inches. For steel rolls, 10 per cent to 20 per cent more thermit is required than for cast iron. It is not necessary to make the roll red-hot; a basketful of coke placed inside the mold until the iron cannot be touched by hand is sufficient. A few sand pits surrounding the roll, and filled with a few hundred-weight of cast iron, will do as well, even with very large rolls.

After firmly imbedding the ring in the mold box, a thin layer of cast iron and steel, say ½ inch, is poured into it, which must completely cover the welding surface. A thin layer of powdered charcoal can be used instead, but has the objection of producing a spray of sparks.

The whole of the thermit, accurately calculated and weighed, is then quickly added and ignited in the usual way, viz.: a thimbleful of ignition powder is placed upon it in a small heap and lighted with a hot iron or a fuse. Immediately after ignition, the mold should be covered with an iron or wood lid, covered with clay on its under side; the wood will char, but not burn.

The reaction, even with large quantities of thermit up to 1½ cwt. at a time, is finished in half a minute, and the lid must at once be removed and the thermit stirred with iron rods so as to disturb the slag (corundum). The heat of the reaction, even with only 20 to 30 kg. thermit, is so intense that the workmen must protect their hands and faces in the usual way for work at crucible furnaces, by using colored glasses, and covering their hands with cloth.

After a few minutes cast iron or steel is poured out of the ladle, which must be in readiness, into the mold to about a third of its capacity. When cast iron is poured on to thermit during reaction, it is especially necessary to stir the metal thoroughly, in order to obtain a thorough mixture of the thermit iron with the cast iron and prevent any steel being formed on the welding surface, but if properly stirred steel never forms.

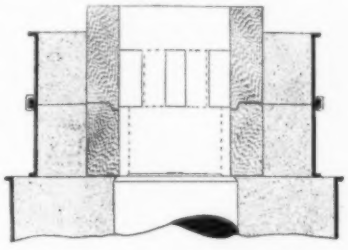


FIG. 2.—THERMIT WELDING OF BROKEN ROLL.

A number of stirring rods must be held in readiness, as the heat melts them quickly, until the cast iron is added. Two or three men ought to be employed simultaneously to stir the metal for several minutes, after which the iron ring is lifted out. The whole of the corundum will then be found adhering to the inner surface of the ring, and is lifted out with it; the ring is protected from melting by the adhering corundum and can be used several times; the ring prevents the slag from clinging to the mold itself.

After withdrawing the ring, more iron, constantly stirred up, is added, until the lower mold is filled. The remaining slag, which will have coagulated in small pieces, is carefully taken off before the second mold, Fig. 2, which may be of trefoil shape, is placed in position.

A great advantage is gained by this method of reducing the waste of metal resulting from the usual rift in the cast. The subsiding takes place very regularly in consequence of the addition of the thermit. The rifts have much less depth, particularly if kept open by pumping with feeding rods as long as possible.

The cast iron added in the process has a peculiarly beautiful and firm structure entirely due to the thermit. What takes place during the welding process is as follows: On the bottom of the mold a number of particles of iron are collected and brought to a very high temperature through the action of the thermit; these have a tendency to rise to the surface, while the upper parts sink to the bottom. This causes a very lively "play" of the iron, and the impurities (particularly of cast iron) are more readily separated off; the cast is therefore appreciably improved; the addition of the thermit also renders the cast iron more fluid, which can be observed even with an addition of only ½ to 1 per cent, but thorough stirring is abso-

lutely necessary in order to obtain a good mixture of the specifically heavier thermit iron with the lighter cast iron.

If the break is cup-shaped, the hollow which is formed must first be filled with cast iron or steel, upon which the thermit is ignited. In order to heat up this greater quantity of metal, an excess of thermit over what is stated above must be used. Such hollow breaks could not be repaired at all by the old method of letting metal run over them. If the break is very slanting, part of the roll must be knocked off to obtain a somewhat horizontal surface, but there is no need to have it absolutely level.

Not only can cast iron or steel be repaired in this way, but a cast boss can be welded on to a steel roll and a steel boss on to a cast iron one. Rolling mills, being as a rule unable to obtain liquid cast iron easily, the latter application is of special interest to them. They need not send the broken roll away, but can repair it in their own shops with liquid steel, and avoid the stoppage of work often necessitated by a broken roll.

It has been calculated by several works who have taken this method into regular use, that the cost is barely half that of the old method, even when the iron which is allowed to overflow can be utilized for smaller and less important casts.

Some works have carefully tested the strength of such thermit welded rolls. Hammer tests have proved that any breaks occur outside the welds. It is interesting to note that test bars cut out of the rolls always tore a long way from the weld.

Of course all solid pieces of metal can be repaired in exactly the same manner as described for rolls.

Welds to be effected upon cast-iron pieces of less solid construction are more difficult, as, in consequence of the "tensions" that exist in every piece of cast iron, breaks occur near the welds. This is particularly the case in repairs of cast-iron boilers, pipes, cylinders, or pulleys. Even with such slight or divided pieces, however, a favorable result may be obtained by first annealing the whole piece. After welding wrought-iron pieces or steel castings, a break in the same place need never be feared if the work has been carefully executed, and the experienced iron founder will find his own way of overcoming all difficulty.

A New Portable Balance.

The accompanying illustrations show a new portable button balance just placed on the market by Wm. Ainsworth & Sons, the well-known balance manufacturers of Denver, Col.

This balance is of the columnless type which has come into such favor for field work during the past few years and is constructed to withstand a moderate amount of rough handling. It has a 5-inch beam, agate edges and bearings, fall-away pan rests, and is made with either single or double-rider apparatus. An improved looking device locks the beam in position on the balance for carrying.

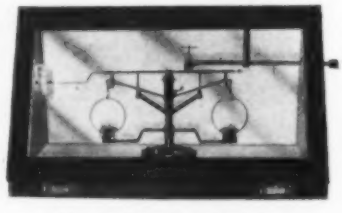


FIG. 1.—PORTABLE BALANCE.

The balance is operated from the left-hand end, and has concealed leveling screws of improved design. Two level vials are placed in the base, instead of a single circular level as sometimes used. The case is of French polished mahogany, and a carrying case of the same material is provided with a leather carrying strap, lock and key.

A combination of the portable button balance with a portable pulp balance in a single carrying case is the most compact and convenient prospecting outfit possible. All parts of the pulp balance pack in the drawer.

Full particulars are given in the Portable Balance Bulletin, sent on request by the manufacturers.

Storage Battery.

The unit accumulator made by the National Battery Co., of Buffalo, N. Y., has a positive plate of the Planté type, and a negative plate of the pasted type. It is built with the view of being used especially for high charge and discharge rates, combined with long life and high efficiency.

Positive plates of the Planté type have a natural tendency to increase in volume or "grow," on account of new active material being formed. In many cases this growth results in the distortion of the plates while in service to such an extent that they have to be removed at frequent intervals to be straightened, which is an expensive operation. In the construction of the positive plate of the unit accumulator, room is provided to care for this natural growth. The units or active portions are hung in a rigid lead frame, with ample space at the bottom, and at the two sides of each unit to allow for expansion, without in the least straightening or distorting the supporting frame.

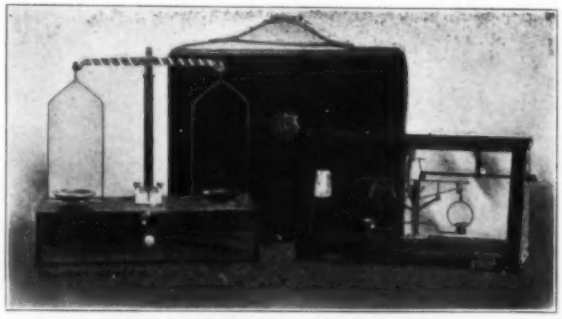


FIG. 2.—COMBINATION BALANCE OUTFIT.

For the negative plate a grid has been developed in which the natural molecular shrinkage of the active material has been provided for, and taken advantage of, so that the contact between active material and grid is maintained as the shrinkage progresses, owing to the fact that the active material enclosed in the contact portions is drawn more tightly around the grid projections or pins. The contact between the active material and the grid is therefore rather improved. The unit accumulator is made by the National Battery Co. in six different types, which are described and illustrated in a pamphlet recently issued by this company.

Industrial Notes.

Emil Greiner, manufacturer and importer of laboratory glassware and apparatus, announces his removal about May 1 to more commodious quarters, at 45 Cliff Street, New York City.

Nernst Lamp.—The Nernst Lamp Co., of Pittsburg, Pa., has issued an artistically illustrated pamphlet on Church Lighting by Electricity, for which purpose the Nernst lamp is specially suitable.

Among the metallurgical machinery shipped during the last three weeks by the Power & Mining Machinery Co., of Cudahy, Wis., were a complete copper converting plant for the Omaha works of the American Smelting & Refining Co.; a 100-ton copper smelting plant for the New England Milling Co., of Greenfield, Mass.; a carload of steel furnace jackets for the new works of the Canadian Copper Co., Copper Cliff, Ont.; a 10-stamp mill complete for Trapper's Flat Mining & Milling Co., Nevada; a Huntington Mill concentrating plant complete for the R. E. Briggs Co., Mexico, and cyanide tanks for the Imperial Gold Mining Co., of Deadwood, S. D. Fifteen

McCully crushers were sold during the first three months of this year.

ELECTRIC POWER IN INDUSTRIAL APPLICATIONS.—The number of motors in use ten years ago in manufacturing plants was very limited, but as the size of factories increased, spreading over greater areas, the older forms of power transmission and machine drive became more impractical, and electricity rapidly moved to the front. This increase in the applications of electric motors has grown to such an extent that it would be difficult to name a single industry into which this form of drive has not entered. As a single instance it may be mentioned that the Alliance Machine Co. and the Morgan Engineering Co., both of Alliance, Ohio, last week placed orders for a total of 120 crane motors, with an aggregate of 2000 horse-power, with the WESTINGHOUSE ELECTRIC & MFG. CO. They vary in size from 1 to 100 horse-power. The Pennsylvania Railroad Co. on the same day contracted for twenty induction motors, to be added to their present equipment, and the Bethlehem Steel Co. entered an order for direct-current motors to be used in their mills. Numerous smaller orders would make up a list of applications which would cover the whole field of motor-driven machines.

The executive offices of the AMERICAN STEEL FOUNDRIES until lately were located at No. 74 Broadway; with the object of concentrating all of the departments it was found necessary to lease the entire eleventh floor of the recently completed building known as No. 42 Broadway, and henceforward communications should be sent to this new address. The executive officers of the American Steel Foundries are inaugurating, simultaneously with the removal, a new system of accounting and distribution of orders, which will improve the organization and simplify their work. The output of their eight plants comprises, mainly, all kinds of steel castings for railway and marine purposes, besides special castings for mining, metallurgical and general engineering purposes.

WESTINGHOUSE ELECTRICAL APPARATUS.—That the steam turbine and turbo-generator are destined to be one of the greatest power developing and distributing factors is evidenced by the number of units of this type which have been installed, and which are now in the process of construction. Owing to the restrictions placed by reciprocating-engine speeds upon the designs of engine-type generating machinery, their dimensions and bulk, as also the cost, have increased enormously in the past few years with the increase in capacity. With the advent of the steam turbine the speeds have increased so as to secure in generator construction minimum bulk and cost consistent with strength and durability. A striking example of this may be seen in the power equipment of the Rapid Transit Company in New York, where turbo-generators, with a rated output of 5000 kw., weighing 234,000 pounds, run at 750 revolutions per minute. Generators of the same output, driven by reciprocating engines at a speed of 75 revolutions per minute, would weigh 980,000 pounds. Orders for eight turbo-generators have been placed with the Westinghouse Electric & Mfg. Co. in the past few days, mostly for 400 and 500 kw. units, with one 2000 kw. and one 2500-kw. machine. Turbo-generators are now being installed in many places where it becomes necessary to increase the output of the station, and where it is not possible to increase the floor space, and also in such cases where the low weight is of importance, in view of transportation difficulties (f. i. to mining camps). Among a great number of orders recently placed with the Westinghouse Co. for electric machines of various types, an order of the Pittsburg Reduction Co. is of special interest to our readers. They will install two new direct-current generators, each rated 2200 kw. at 500 volts. These machines will run at 140 revolutions per minute, and embody all the lastest features of Westinghouse design.

The new plant at Ithaca, of the MORSE CHAIN CO., Trumansburg, N. Y., will consist of machine shop, forge shop, hardening and tempering shop, wood shop, pattern storage, foundry and offices. The power plant will consist of Westinghouse single-acting compound engines direct connected to 80-kw., 125-volt, direct-current generators from the World's Fair at St. Louis, supplied by Babcock & Wilcox boilers at 130-pound pressure. The machine shop equipment will be modern in every respect, with individual and group drives from 110-volt motors. Work of completing the details is now progressing rapidly, preparatory to commencing work of erection in the spring. The silent chain of the Morse Chain Co. was described in our Vol. II, page 515.

PRICE LIST OF CHEMICALS.—We have received from Messrs. CHAS. COOPER & CO., 194 Worth Street, New York City, their regular price list of chemicals for laboratory and industrial work. The price list is issued monthly, and is sent on request to all interested parties.

The INDUSTRIAL LABORATORIES, of 164 Front Street, New York City (Dr. J. E. Teeple, director), which were established for chemical research and analyses, have recently purchased a large part of the splendid German Government exhibit of chemical laboratory apparatus at St. Louis. Their laboratory is now believed to be one of the most completely equipped with modern facilities in the world.

The CROCKER-WHEELER CO. has been awarded the contract for four 4000-kw. three-phase 60-cycle alternators for a hydro-electric station at Lockport, Ill., near Chicago. The company has been building and marketing for the past eight months a line of alternating-current generators of the engine, belt, water-wheel and turbine types, according to the renowned designs of the Brown-Boveri Co., of Switzerland (who, by the way, have installed numerous machines in various prominent electrometallurgical works of Europe). This latest contract, with the recent order for three 4000-kw. alternators, to be driven by gas engines, places the Crocker-Wheeler Co. in the front rank of American manufacturers of alternating-current generators of large capacity.

PRICE LIST OF CHEMICALS.—A neat "blue book," recently issued by the Charles E. Sholes Co., 164 Front Street, New York, contains one of the most complete and conveniently arranged lists of chemicals which has ever come into our hands. The list has evidently been prepared with a full appreciation of what is needed for laboratory work as well as for commercial purposes. The chemicals are arranged in alphabetical order. The president of the company is Mr. Charles E. Sholes, who is widely known through his former connection with the General Chemical Co. as assistant manager of the sales. The price list distinguishes between C. P. (construed to mean strictly chemically pure), U. S. P. (indicating a degree of purity which fully conforms to United States Pharmacopœia standards), and Pure (a grade of their own, manufactured to meet special commercial requirements).

NATIONAL ELECTRIC CO.—The First National Bank of Milwaukee has had assigned to it about two-thirds of the capital stock of the National Electric Co., as security for loans. The bank has now taken over the control of the latter company, and John I. Beggs, Charles V. Pfister, Frederick Vogel, Jr., J. H. Van Dyke, Jr., all First National Bank directors, have been elected directors of the National Electric Co., replacing S. W. Watkins, president; F. H. Bigelow, chairman of board; F. C. Randall, director, vice-president and general manager, and Gordon Bigelow. Former Directors A. N. McGeoch and B. T. Becker will remain on the board. John I. Beggs has been elected and accepted the presidency of the company, and will direct its affairs. Mr. Beggs announces that the business of the company will be actively continued and all contracts promptly completed. The indebtedness is now being ascertained, and when it is known, a meeting of the creditors will be called to consider the best plan to protect all creditors and promote the future welfare and progress of the company, which Mr. Beggs believes can be made successful and profitable.

Personal.

Mr. C. C. Speiden, manager of the chemical department of A. Klipstein & Co., sailed with his family on April 29 for a few weeks' vacation in Europe.

Messrs. Byrnes & Townsend, patent lawyers in Washington, D. C., announce that they have associated with them Mr. Eugene C. Brown, late examiner of alternating-current machinery and system in the United States Patent Office, and that they give special attention to electrical, chemical and metallurgical lines, including soliciting, expert testimony and interference and court practice.

In the investigation of the internal affairs of the Equitable Life Assurance Society, to be conducted by a committee of the Board of Directors, Mr. Henry C. Frick, as chairman of this committee, has selected as his principal assistant Mr. F. W. Haskell, widely known in electrochemical and metallurgical circles as the president of the Carborundum Company, of Niagara Falls. The New York *Herald* writes: "Mr. Haskell was formerly secretary and treasurer of the Southwest Connellsville Coke Company at Pittsburg, and is a man who has a considerable reputation as an auditor and mathematician."

Mr. F. E. Drake, recently president of the Lanyon Zinc Company, and formerly director of machinery and electricity for the United States at the Paris Exposition of 1900, sailed on the Kaiser Wilhelm II for Europe, where he will take over the management of the interests of the Chicago Pneumatic Tool Company, whose business on the Continent has assumed such proportions as to require the establishment of a principal office at Berlin, where Mr. Drake will reside. Following the Paris Exposition work, Mr. Drake devoted nearly two years to the reorganization of the works of the Union Electricitäts Gesellschaft, which is now controlled by the Allgemeine Electricitäts Gesellschaft, so that he goes to a field in which he has a large acquaintance and a wide experience. During the past two years Mr. Drake has paid close attention to the possibilities of electric smelting, and has directed some very important experiments in electric furnace methods.

Mr. Wm. Howard Cole, who has been connected with Goldschmidt Thermit Co., of New York City, in the capacity of chief engineer for the past nine months, has resigned his position and has left for Europe, in order to pursue professional work in connection with electric tramways. Mr. R. F. Kelker, Jr., has taken up the position as engineer for the Goldschmidt Thermit Co., and will superintendent the Street Railway Department. Mr. Kelker was lately connected as assistant engineer with the Brooklyn Heights Railroad.

Mr. Chas. B. Jacobs has opened a chemical and electrochemical laboratory at 52 Beaver Street, New York, for the purpose of carrying on general consulting and industrial research work, especially examination of and report on new processes, improvements in existing processes and plants, research and development work on the utilization of waste products, etc. Mr. Jacobs was graduated at the School of Chemistry, Lehigh University. He was for several years connected with the General Electric Co., in charge of the chemical laboratory at Schenectady, and for the past seven years has been actively engaged in experimental and development work, having been closely connected with some of the recent developments of electrochemical industries at Niagara Falls.

Digest of U. S. Patents.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

Electric Smelting and Reduction Processes.

(*Continued from page* 164.)

575,788, January 26, 1897, T. L. Willson, New York, N. Y.

Aluminium bronze is produced in accordance with the general process of patent 491,394, powdered alumina and crushed carbon, intimately mixed, being heated in an electric arc in the presence of a base metal capable of alloying with aluminium. It is stated that the output of product for the energy consumed is nearly doubled by the use of an alternating arc of appropriate volume and frequency, it being alleged that the alternate expansion and contraction of the gases produced by the arc keeps the mass in the furnace in constant and rapid vibration, whereby fresh material is automatically brought into the zone of reduction. In a specific example a current of 1500 amperes at 55 volts and having a frequency of 60 cycles per second is named. The specific application of this method to the production of calcium carbide is described.

577,802, February 23, 1897, Gustaf M. Westman, New York.

A furnace for the treatment of mispickel and other ores of arsenic comprises a closed chamber in the bottom of which is a pool of metallic lead, maintained melted during the operation and serving as the cathode of an electric circuit. The anode is an iron block adjustably supported in the furnace roof. The sides of the anode are enameled with a slag composition in order to prevent the adherence of metallic arsenic. The arsenical ores are introduced between the electrodes and heated by the current, the arsenic distilling into a suitable condenser while any precious metals are retained by the lead cathode. The residual ferrous-sulphide is tapped from the furnace at the close of the operation.

588,266, August 17, 1897, G. De Chalmot, Leaksville, N. C.

Smelts phosphate rock to render it more soluble. The rock is broken into lumps and fed into an arc furnace, wherein it is continuously melted and overflows at one side. The furnace has side walls of phosphate rock and a horizontal bottom of carbon, supported on an iron plate and serving as one electrode. The other electrode is a group of carbon bars depending into the furnace. The molten phosphate is run onto a horizontal, hollow, revolving iron drum, which may be internally cooled by water. Sand is simultaneously fed onto the drum, to cover it with a protecting layer and to react with the molten phosphate with the formation of a silico-phosphate of lime. The product falls from the drum into a water tank and is thereby cracked in all directions. When most of the water in the tank is evaporated it is inverted, and the phosphate falls onto a grating. It is then crushed to powder, for use as a fertilizer. The percentage of phosphoric acid is thus raised from 23 to 29.50, and the portion which is soluble in Wagner's citrate solution from 1.39 to 9.50. The liquid phosphate in the bottom of the furnace is not run off, as it contains calcium phosphide, due to reduction at the carbon bottom.

589,161, August 31, 1897, Frederic Chaplet, Laval, France.

Produces hard bodies for cutting chrome steel, rubies, sapphires and diamonds. The bodies contain a metalloid such as carbon or silicon, and a metal, such as titanium, chromium, molybdenum or tungsten, or three of these constituents. Specifically, produces silicon titanid; silicon carbo-titanid; chromium silicide, molybdenum carbo-silicide, and tungsten carbo-silicide. The charge usually contains oxides of the metals and carbon in the form of pulverized coke, the carbon being either in equivalent proportions or excess, according to the desired product. The mixture is smelted and allowed to cool and crystallize.

589,415, September 7, 1897, G. De Chalmot, Leaksville, N. C.

Produces crystalline silicon by first producing an alloy of silicon and a silicide of calcium, iron or manganese. The alloy is boiled with hydrochloric or sulfuric acid, then treated with hydrofluoric acid and washed, whereby the silicides are dissolved out. Calcium silicide can be separated by running water, the resulting silicide acid being washed out or dissolved in an alkaline solution. Mentions a silicon alloy of tungsten and silver containing free silicon. The charge, a mixture of silica or a silicate, a metallic oxide or salt and carbon, is smelted with an arc, the current being high and the voltage low except at starting. A direct current is employed and the alloy is deposited upon the cathode.